US011958196B2

(12) **United States Patent**
Yamashita et al.

(10) **Patent No.: US 11,958,196 B2**
(45) **Date of Patent: Apr. 16, 2024**

(54) **PRODUCTION SYSTEM AND INFORMATION STORAGE MEDIUM**

(71) Applicant: **Kabushiki Kaisha Yaskawa Denki**, Kitakyushu (JP)

(72) Inventors: **Takeshi Yamashita**, Kitakyushu (JP); **Ryosuke Tsutsumi**, Kitakyushu (JP)

(73) Assignee: **KABUSHIKI KAISHA YASKAWA DENKI**, Fukuoka (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 151 days.

(21) Appl. No.: **17/123,075**

(22) Filed: **Dec. 15, 2020**

(65) **Prior Publication Data**

US 2021/0178589 A1 Jun. 17, 2021

(30) **Foreign Application Priority Data**

Dec. 17, 2019 (JP) 2019-227306

(51) **Int. Cl.**
B25J 9/16 (2006.01)
B25J 13/08 (2006.01)

(52) **U.S. Cl.**
CPC ***B25J 9/1664*** (2013.01); ***B25J 9/163*** (2013.01); ***B25J 9/1661*** (2013.01); ***B25J 13/089*** (2013.01)

(58) **Field of Classification Search**
CPC B25J 9/1664; B25J 9/163; B25J 9/1161; B25J 13/089; B25J 9/162; G05B 2219/39175; G05B 2219/40284; G05B 2219/40298; G05B 19/4185; G05B 2219/32252
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,631,028 A * 5/1997 Mizokawa B29D 30/0016 425/29
9,744,665 B1 * 8/2017 Linnell B25J 9/10
11,203,120 B1 * 12/2021 Hill B25J 9/0087
2010/0217437 A1 8/2010 Sarh et al.
2013/0245823 A1 9/2013 Kimura et al.
2014/0207280 A1 7/2014 Duffley et al.
2014/0207281 A1 7/2014 Angle et al.
2014/0207282 A1 7/2014 Angle et al.
(Continued)

FOREIGN PATENT DOCUMENTS

CN 103317497 A 9/2013
CN 105426257 A 3/2016
(Continued)

OTHER PUBLICATIONS

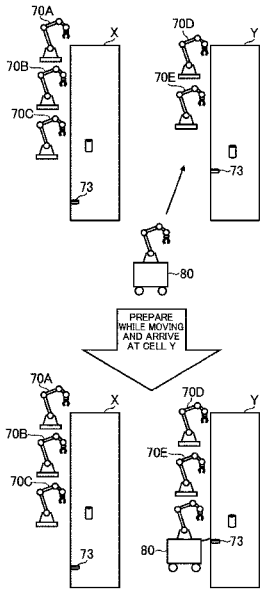
Search Report of May 18, 2021, for corresponding EP Patent Application No. 20213755.0 pp. 1-8.
(Continued)

Primary Examiner — Jason Holloway
Assistant Examiner — Blake A Wood
(74) *Attorney, Agent, or Firm* — HEA LAW PLLC

(57) **ABSTRACT**

A production system comprising: an industrial device being self-movable; and circuitry configured to; control the industrial device to prepare for a next job before the industrial device arrives at a next location; and control the industrial device to perform the next job when the industrial device arrives at the next location and a preparation for the next job is completed.

19 Claims, 13 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2014/0350725	A1*	11/2014	LaFary	B25J 9/1676 901/50
2014/0365258	A1*	12/2014	Vestal	G05D 1/0297 901/1
2016/0167234	A1	6/2016	Angle et al.	
2016/0282862	A1	9/2016	Duffley et al.	
2016/0282863	A1	9/2016	Angle et al.	
2017/0015373	A1	1/2017	Thorwarth	
2017/0015374	A1	1/2017	Thorwarth	
2017/0185076	A1	6/2017	Yamamoto et al.	
2018/0071918	A1	3/2018	Angle et al.	
2018/0222047	A1	8/2018	Nishi	
2018/0304472	A1	10/2018	Angle et al.	
2019/0097827	A1	3/2019	Angle et al.	
2019/0127000	A1	5/2019	Eberl	
2019/0172488	A1*	6/2019	Goodman	G11B 15/6835
2019/0370689	A1	12/2019	Ando et al.	
2020/0298408	A1*	9/2020	Hashimoto	B25J 9/1682
2021/0170601	A1*	6/2021	Saito	B65G 1/0435
2022/0212346	A1*	7/2022	Toritani	B25J 9/1661

FOREIGN PATENT DOCUMENTS

CN	106103006	A	11/2016
CN	107518826	A	12/2017
CN	108873913	A	11/2018
CN	109070291	A	12/2018
CN	208775706	U	4/2019
CN	109748203	A	5/2019
CN	110235137	A	9/2019
CN	110355759	A	10/2019
EP	0704780	A1	4/1996
EP	2939798	A1	11/2015
JP	H07-281721	A	10/1995
JP	H08-290350	A	11/1996
JP	2005-238391	A	9/2005
JP	2014-144490	A	8/2014
JP	2017-132002	A	8/2017
WO	2005/091090	A2	9/2005
WO	WO-2010043640	A2 *	4/2010 B25J 5/007

OTHER PUBLICATIONS

Office Actions of Mar. 17, 2020, for corresponding JP application No. 2019-227306 with the partial translation of the Office Action.
Office Actions of Aug. 11, 2020, for corresponding JP application No. 2019-227306 with he partial translation of the Office Action.
Office Action of Dec. 19, 2023, for corresponding CN Patent Application No. 202011417337.4 with translation, pp. 1-18.

* cited by examiner

FIG.1

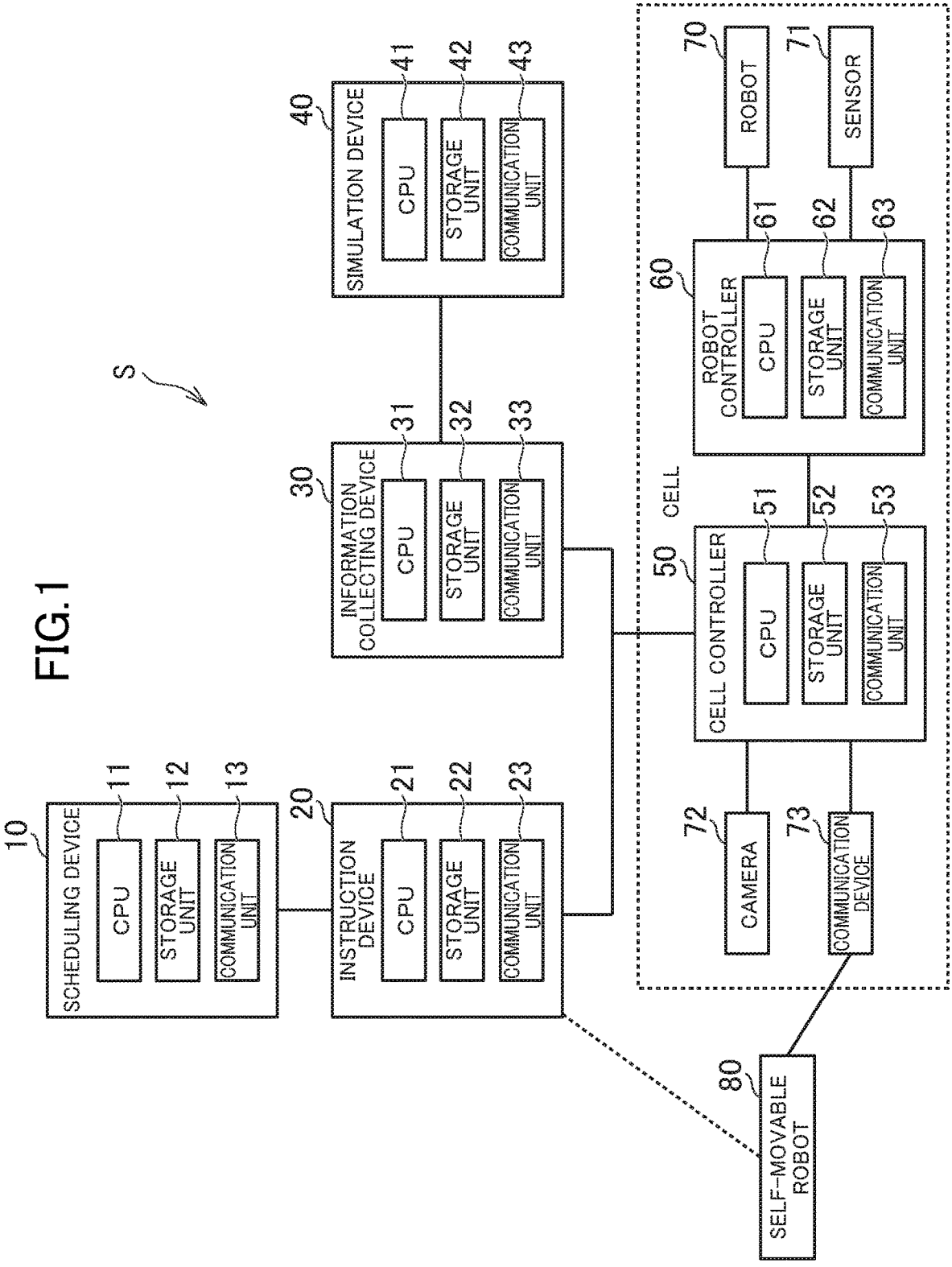

S
10
SCHEDULING DEVICE
11
CPU
12
STORAGE UNIT
13
COMMUNICATION UNIT
20
INSTRUCTION DEVICE
21
CPU
22
STORAGE UNIT
23
COMMUNICATION UNIT
30
INFORMATION COLLECTING DEVICE
31
CPU
32
STORAGE UNIT
33
COMMUNICATION UNIT
40
SIMULATION DEVICE
41
CPU
42
STORAGE UNIT
43
COMMUNICATION UNIT
CELL
50
CELL CONTROLLER
51
CPU
52
STORAGE UNIT
53
COMMUNICATION UNIT
60
ROBOT CONTROLLER
61
CPU
62
STORAGE UNIT
63
COMMUNICATION UNIT
70
ROBOT
71
SENSOR
72
CAMERA
73
COMMUNICATION DEVICE
80
SELF-MOVABLE ROBOT

FIG.2

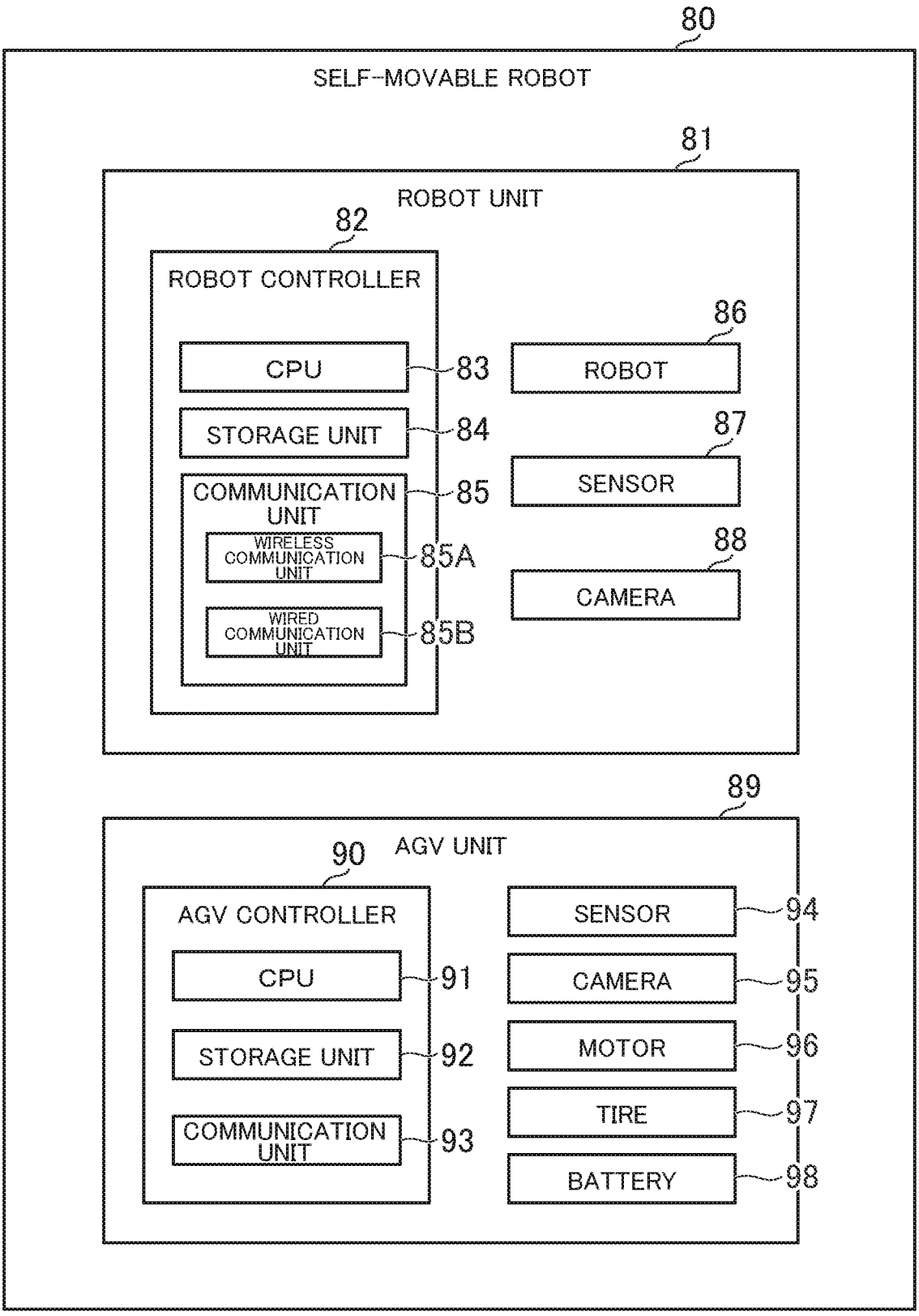

80
SELF-MOVABLE ROBOT
81
ROBOT UNIT
82
ROBOT CONTROLLER
CPU
83
STORAGE UNIT
84
COMMUNICATION UNIT
85
WIRELESS COMMUNICATION UNIT
85A
WIRED COMMUNICATION UNIT
85B
86
ROBOT
87
SENSOR
88
CAMERA
89
AGV UNIT
90
AGV CONTROLLER
CPU
91
STORAGE UNIT
92
COMMUNICATION UNIT
93
SENSOR
94
CAMERA
95
MOTOR
96
TIRE
97
BATTERY
98

FIG.3

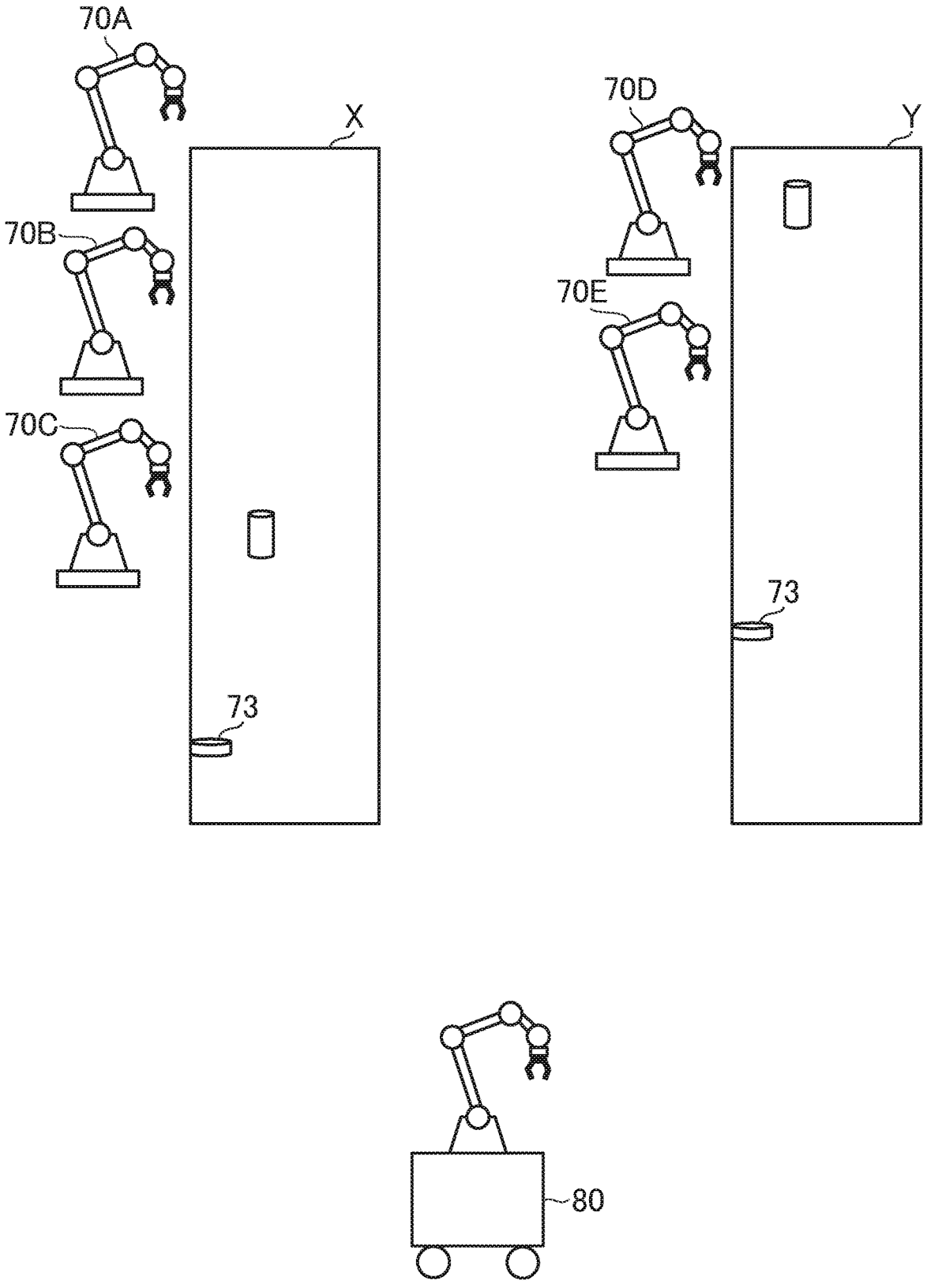


FIG.4

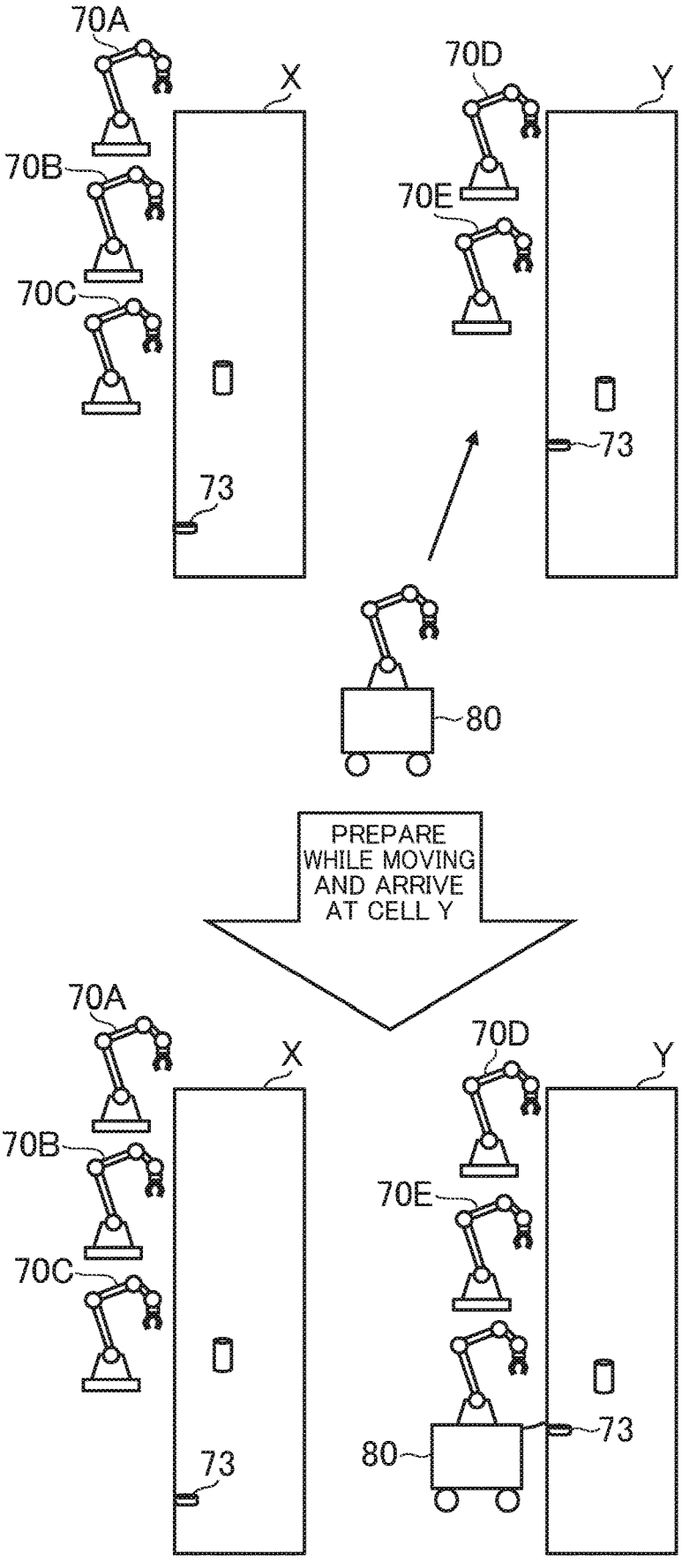

70A
X
70B
70C
73
70D
Y
70E
73
80
PREPARE WHILE MOVING AND ARRIVE AT CELL Y
70A
X
70B
70C
73
70D
Y
70E
80
73

FIG.5

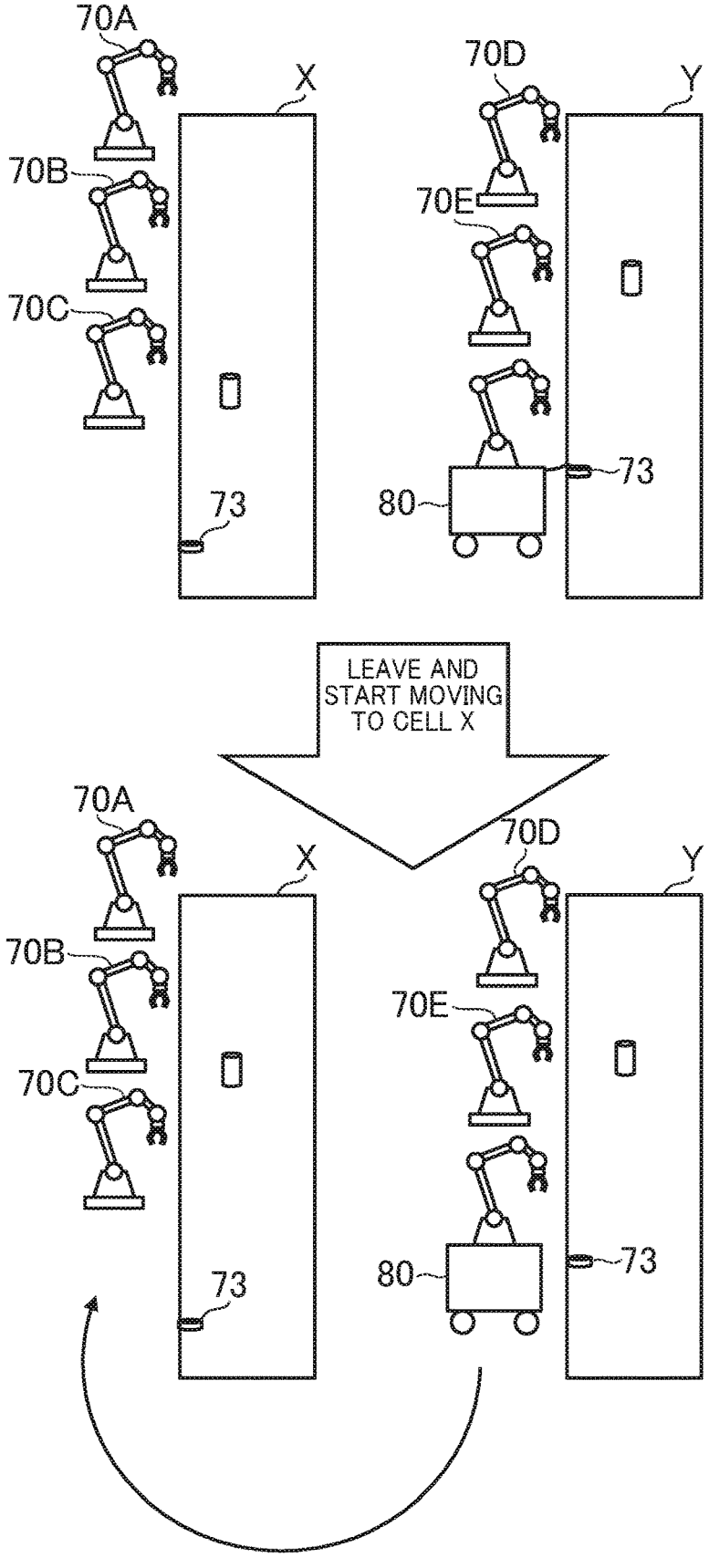

70A
X
70D
Y
70B
70E
70C
73
80
73
LEAVE AND START MOVING TO CELL X
70A
X
70D
Y
70B
70E
70C
73
80
73

FIG.6

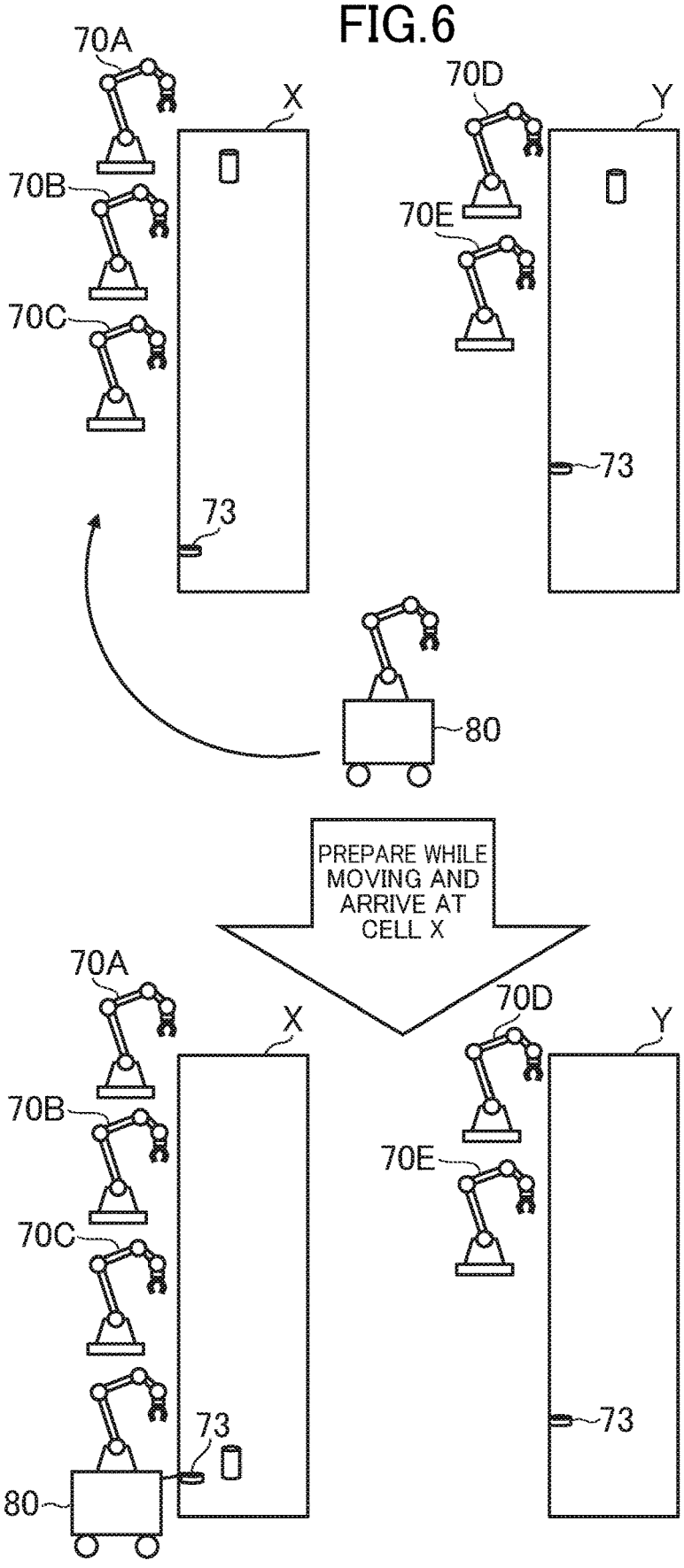

70A
X
70D
Y
70B
70E
70C
73
73
80
PREPARE WHILE MOVING AND ARRIVE AT CELL X
70A
X
70D
Y
70B
70E
70C
73
73
80

FIG. 7

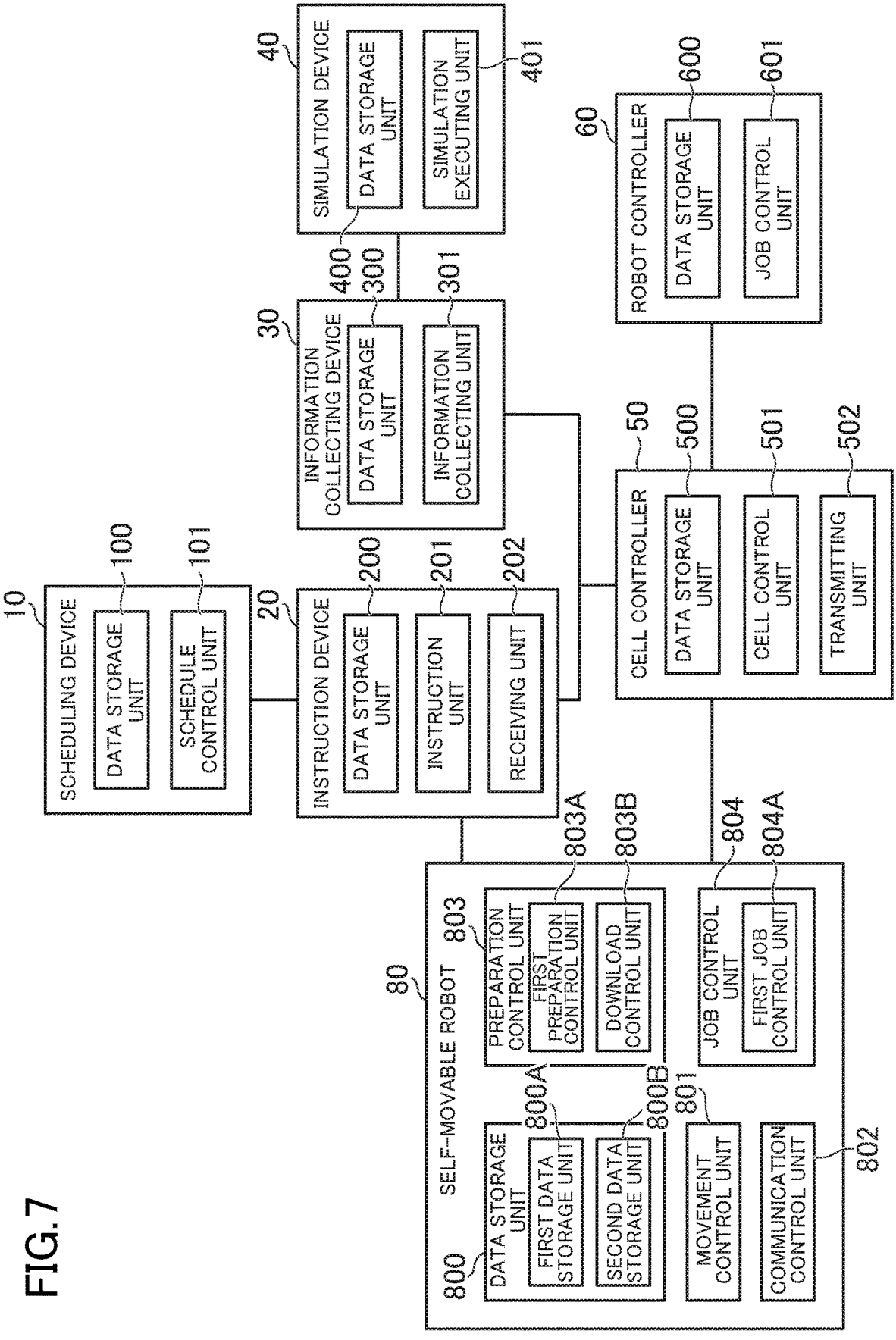

10
SCHEDULING DEVICE
100
DATA STORAGE UNIT
101
SCHEDULE CONTROL UNIT
20
INSTRUCTION DEVICE
200
DATA STORAGE UNIT
201
INSTRUCTION UNIT
202
RECEIVING UNIT
30
INFORMATION COLLECTING DEVICE
300
DATA STORAGE UNIT
301
INFORMATION COLLECTING UNIT
40
SIMULATION DEVICE
400
DATA STORAGE UNIT
401
SIMULATION EXECUTING UNIT
50
CELL CONTROLLER
500
DATA STORAGE UNIT
501
CELL CONTROL UNIT
502
TRANSMITTING UNIT
60
ROBOT CONTROLLER
600
DATA STORAGE UNIT
601
JOB CONTROL UNIT
80
SELF-MOVABLE ROBOT
800
DATA STORAGE UNIT
800A
FIRST DATA STORAGE UNIT
800B
SECOND DATA STORAGE UNIT
801
MOVEMENT CONTROL UNIT
802
COMMUNICATION CONTROL UNIT
803
PREPARATION CONTROL UNIT
803A
FIRST PREPARATION CONTROL UNIT
803B
DOWNLOAD CONTROL UNIT
804
JOB CONTROL UNIT
804A
FIRST JOB CONTROL UNIT

FIG.8

JOB ORDER	JOB ID	CELL ID	INDUSTRIAL DEVICE ID	CONTENT OF JOB
1	p00001	s00001	i00001,i00002	PRODUCE PRODUCT A
2	p00002	s00002	i00004,i00009・・・	PROCESS JOBPIECE B
3	p00003	s00004	i00010	PACK PRODUCT C
・	・	・	・	・
・	・	・	・	・
・	・	・	・	・

FIG.9

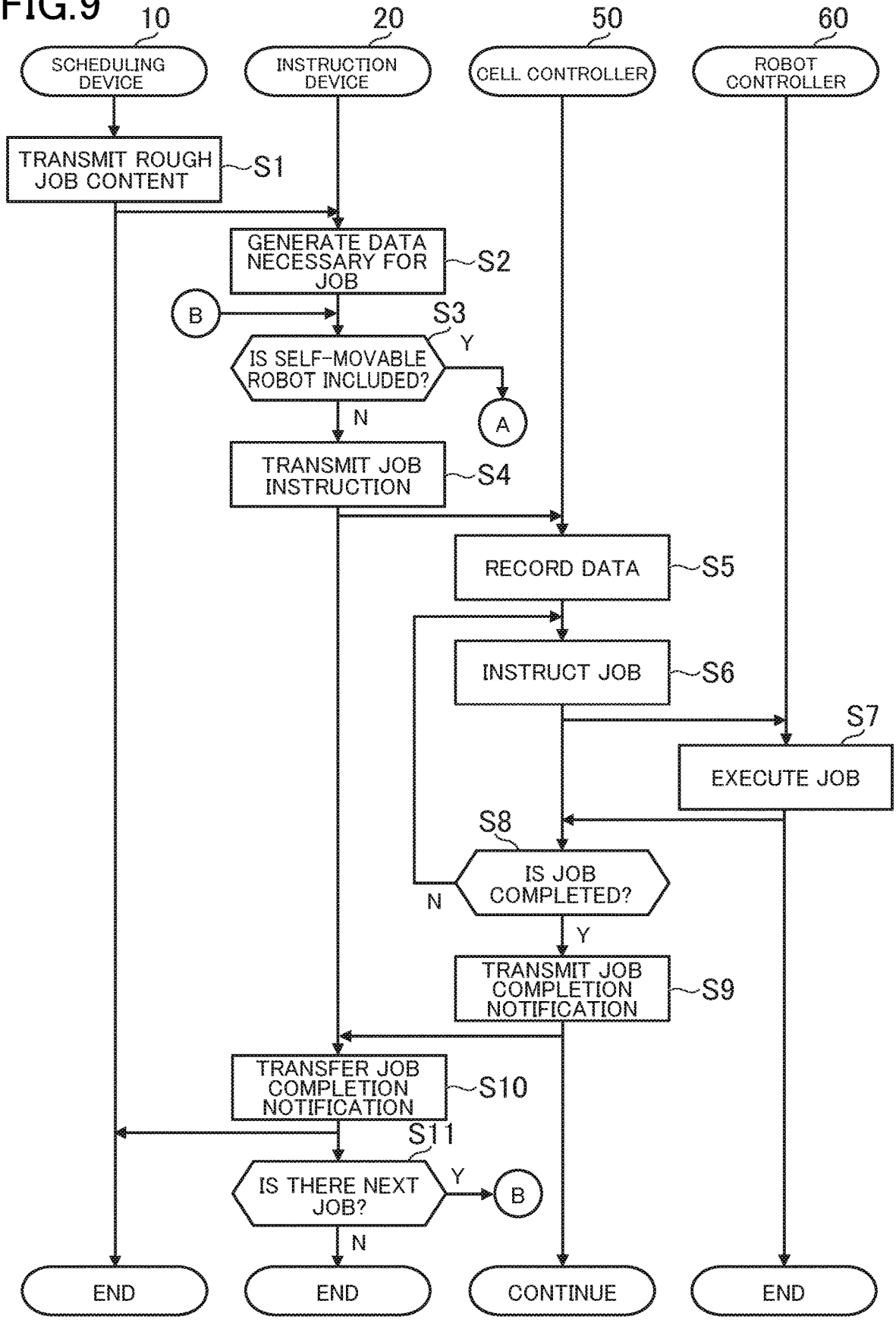

10
SCHEDULING DEVICE
20
INSTRUCTION DEVICE
50
CELL CONTROLLER
60
ROBOT CONTROLLER
TRANSMIT ROUGH JOB CONTENT
S1
GENERATE DATA NECESSARY FOR JOB
S2
B
S3
IS SELF-MOVABLE ROBOT INCLUDED?
Y
A
N
TRANSMIT JOB INSTRUCTION
S4
RECORD DATA
S5
INSTRUCT JOB
S6
S7
EXECUTE JOB
S8
IS JOB COMPLETED?
N
Y
TRANSMIT JOB COMPLETION NOTIFICATION
S9
TRANSFER JOB COMPLETION NOTIFICATION
S10
S11
IS THERE NEXT JOB?
Y
B
N
END
END
CONTINUE
END

FIG.10

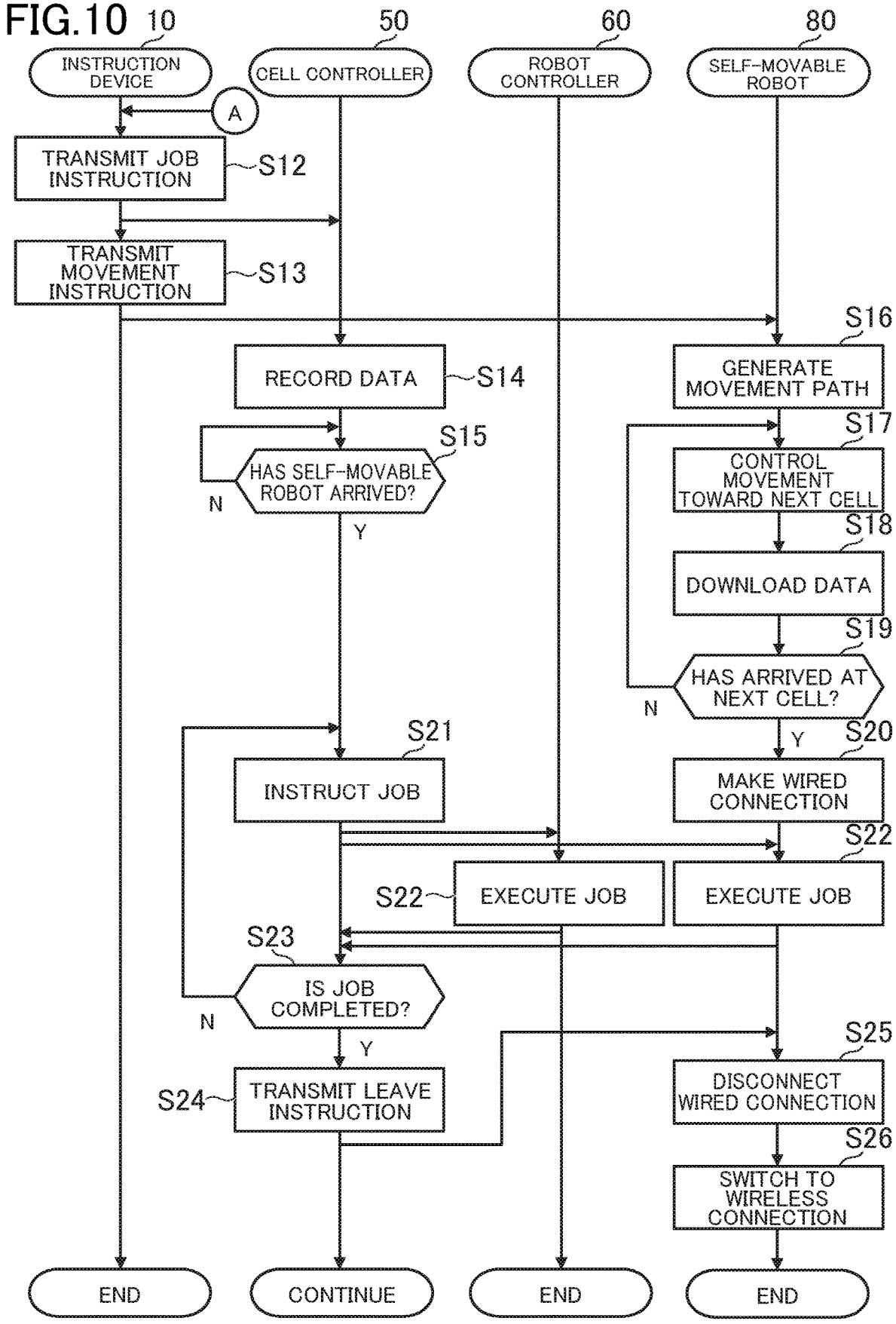

10
50
60
80
INSTRUCTION DEVICE
CELL CONTROLLER
ROBOT CONTROLLER
SELF-MOVABLE ROBOT
A
TRANSMIT JOB INSTRUCTION
S12
TRANSMIT MOVEMENT INSTRUCTION
S13
S16
RECORD DATA
S14
GENERATE MOVEMENT PATH
S15
S17
HAS SELF-MOVABLE ROBOT ARRIVED?
N
Y
CONTROL MOVEMENT TOWARD NEXT CELL
S18
DOWNLOAD DATA
S19
HAS ARRIVED AT NEXT CELL?
N
Y
S21
S20
INSTRUCT JOB
MAKE WIRED CONNECTION
S22
S22
EXECUTE JOB
EXECUTE JOB
S23
IS JOB COMPLETED?
N
Y
S25
S24
TRANSMIT LEAVE INSTRUCTION
DISCONNECT WIRED CONNECTION
S26
SWITCH TO WIRELESS CONNECTION
END
CONTINUE
END
END

FIG.11

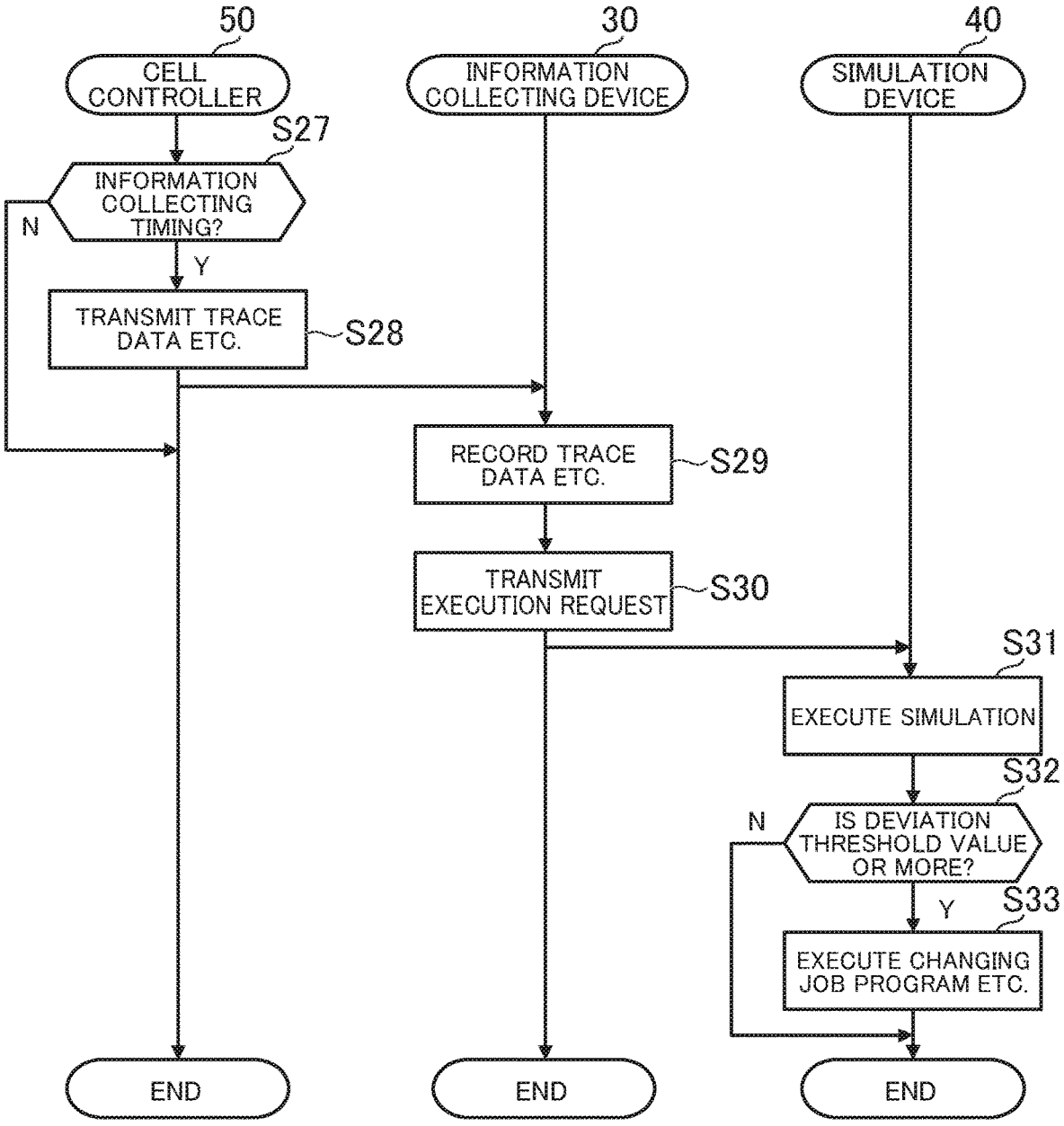

50
CELL CONTROLLER
30
INFORMATION COLLECTING DEVICE
40
SIMULATION DEVICE
S27
INFORMATION COLLECTING TIMING?
N
Y
TRANSMIT TRACE DATA ETC.
S28
RECORD TRACE DATA ETC.
S29
TRANSMIT EXECUTION REQUEST
S30
S31
EXECUTE SIMULATION
S32
N
IS DEVIATION THRESHOLD VALUE OR MORE?
Y
S33
EXECUTE CHANGING JOB PROGRAM ETC.
END
END
END

FIG.12

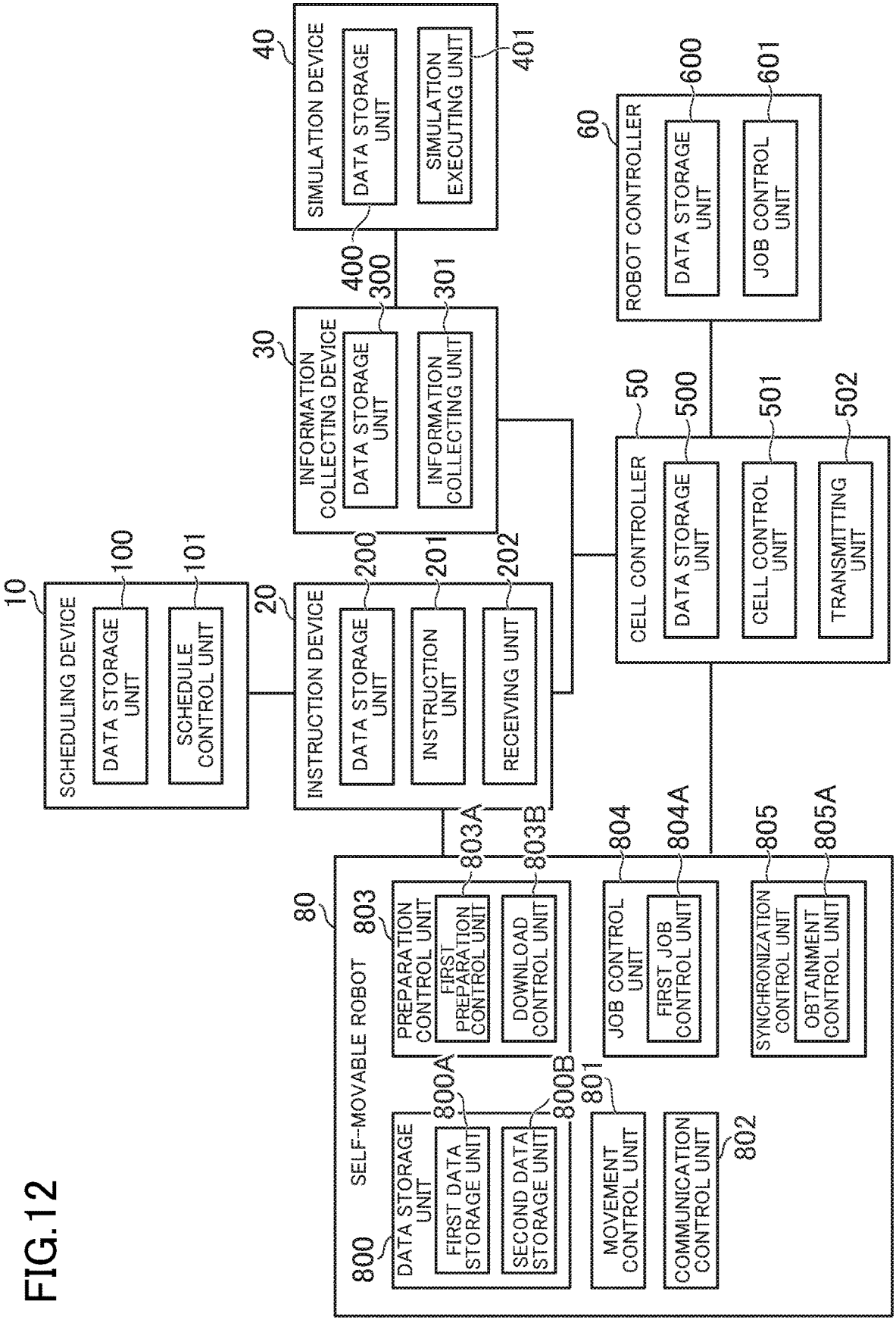
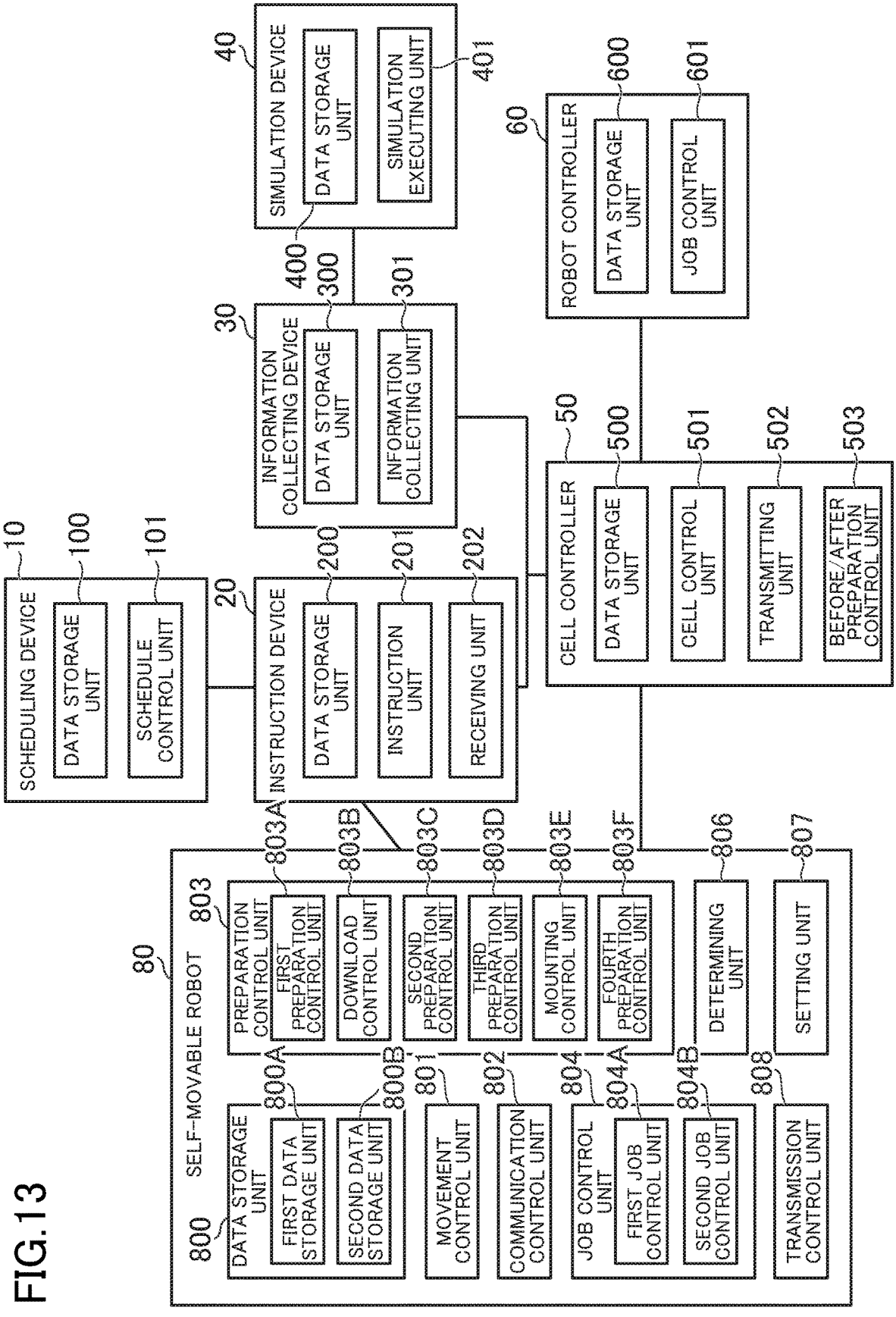

10
SCHEDULING DEVICE
100
DATA STORAGE UNIT
101
SCHEDULE CONTROL UNIT
20
INSTRUCTION DEVICE
200
DATA STORAGE UNIT
201
INSTRUCTION UNIT
202
RECEIVING UNIT
30
INFORMATION COLLECTING DEVICE
300
DATA STORAGE UNIT
301
INFORMATION COLLECTING UNIT
400
40
SIMULATION DEVICE
DATA STORAGE UNIT
401
SIMULATION EXECUTING UNIT
50
CELL CONTROLLER
500
DATA STORAGE UNIT
501
CELL CONTROL UNIT
502
TRANSMITTING UNIT
60
ROBOT CONTROLLER
600
DATA STORAGE UNIT
601
JOB CONTROL UNIT
80
SELF-MOVABLE ROBOT
800
DATA STORAGE UNIT
800A
FIRST DATA STORAGE UNIT
800B
SECOND DATA STORAGE UNIT
801
MOVEMENT CONTROL UNIT
802
COMMUNICATION CONTROL UNIT
803
PREPARATION CONTROL UNIT
803A
FIRST PREPARATION CONTROL UNIT
803B
DOWNLOAD CONTROL UNIT
804
JOB CONTROL UNIT
804A
FIRST JOB CONTROL UNIT
805
SYNCHRONIZATION CONTROL UNIT
805A
OBTAINMENT CONTROL UNIT

FIG.13


10
SCHEDULING DEVICE
100
DATA STORAGE UNIT
101
SCHEDULE CONTROL UNIT
20
INSTRUCTION DEVICE
200
DATA STORAGE UNIT
201
INSTRUCTION UNIT
202
RECEIVING UNIT
30
INFORMATION COLLECTING DEVICE
300
DATA STORAGE UNIT
301
INFORMATION COLLECTING UNIT
40
SIMULATION DEVICE
400
DATA STORAGE UNIT
401
SIMULATION EXECUTING UNIT
50
CELL CONTROLLER
500
DATA STORAGE UNIT
501
CELL CONTROL UNIT
502
TRANSMITTING UNIT
503
BEFORE/AFTER PREPARATION CONTROL UNIT
60
ROBOT CONTROLLER
600
DATA STORAGE UNIT
601
JOB CONTROL UNIT
80
SELF-MOVABLE ROBOT
800
DATA STORAGE UNIT
800A
FIRST DATA STORAGE UNIT
800B
SECOND DATA STORAGE UNIT
801
MOVEMENT CONTROL UNIT
802
COMMUNICATION CONTROL UNIT
803
PREPARATION CONTROL UNIT
803A
FIRST PREPARATION CONTROL UNIT
803B
DOWNLOAD CONTROL UNIT
803C
SECOND PREPARATION CONTROL UNIT
803D
THIRD PREPARATION CONTROL UNIT
803E
MOUNTING CONTROL UNIT
803F
FOURTH PREPARATION CONTROL UNIT
804
JOB CONTROL UNIT
804A
FIRST JOB CONTROL UNIT
804B
SECOND JOB CONTROL UNIT
806
DETERMINING UNIT
807
SETTING UNIT
808
TRANSMISSION CONTROL UNIT

PRODUCTION SYSTEM AND INFORMATION STORAGE MEDIUM

CROSS-REFERENCE TO RELATED APPLICATION

The present disclosure contains subject matter related to that disclosed in Japanese Patent Application JP2019-227306 filed in the Japan Patent Office on Dec. 17, 2019 the entire contents of which are hereby incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The embodiments disclosed herein relate to a production system and an information storage medium.

2. Description of the Related Art

JP2017-132002A describes a self-movable industrial device having a robot arm mounted on an automatic carrier, and a power accumulation part for accumulating power supplied through a connection part connected to/removed from a power supply source and supplying power to the robot arm.

SUMMARY OF THE INVENTION

A production system according to one aspect of the present invention includes an industrial device being self-movable; and circuitry configured to; control the industrial device to prepare for a next job before the industrial device arrives at a next location; and control the industrial device to perform the next job when the industrial device arrives at the next location and a preparation for the next job is completed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagram illustrating an example of an overall configuration of a production system according to embodiment 1.

FIG. **2** is a diagram illustrating an example of a detailed configuration of a self-movable robot.

FIG. **3** is a diagram illustrating an example of a cell in a production system.

FIG. **4** is a diagram illustrating an example of a cell in a production system.

FIG. **5** is a diagram illustrating an example of a cell in a production system.

FIG. **6** is a diagram illustrating an example of a cell in a production system.

FIG. **7** is a functional block diagram showing functions implemented in the production system.

FIG. **8** is a diagram illustrating an example of data storage of schedule data.

FIG. **9** is a flow chart showing processing executed in the production system.

FIG. **10** is a flow chart showing processing executed in the production system.

FIG. **11** is a flow chart showing processing executed in the production system.

FIG. **12** is a functional block diagram of embodiment 2.

FIG. **13** is a functional block diagram of a modification example.

DESCRIPTION OF THE EMBODIMENTS

1. Embodiment 1

The inventors have considered moving a self-movable industrial device to each of a plurality of locations sequentially to execute a job. In this case, it is necessary to have the self-movable industrial device prepare for the job at each location. For example, if the self-movable industrial device arrives at a location and then starts preparation for the job at the location, the job cannot be started until the preparation is completed, and the production efficiency in the production system decreases. Accordingly, as a result of intensive research and development to improve production efficiency in the production system, the inventors have conceived of a new and original production system. In the following, an embodiment (hereinafter referred to as embodiment 1) of the production system will be described.

[1-1. Overall Configuration of Production System]

FIG. **1** is a diagram illustrating an example of an overall configuration of a production system according to the embodiment 1. As shown in FIG. **1**, a production system S includes a scheduling device **10**, an instruction device **20**, an information collecting device **30**, a simulation device **40**, a cell controller **50**, a robot controller **60**, a robot **70**, and a self-movable robot **80**, for example. FIG. **1** shows one device for each device, although there may be a plurality of each device. The production system S may include other devices, or some devices may be omitted.

The scheduling device **10** is a computer that manages a schedule of the entire production system S. A schedule is a plan that indicates when and what a job to do, and may also be referred to as a production plan or a job plan. In the present embodiment, the production system S includes a plurality of cells, and the scheduling device **10** manages schedules of the cells. For example, the scheduling device **10** manages a rough schedule such as when and what a job is to be performed in each cell, and the instruction device **20** determines a specific job.

A cell is a group in the production system S and similar to a line in terms of a concept. In this embodiment, a cell is smaller unit than a line, but the concept of the cell is not limited to this. There may be only one cell. At least one industrial device belongs to a cell. The Industrial devices belonging to the same cell execute a job in cooperation with each other. In this embodiment, the self-movable robot **80** joins and leaves the cell, and thus the number of industrial devices belonging to the cell fluctuates.

The industrial device is a device for performing a job on behalf of a human being. The industrial device performs the job on a job object. For example, the cell controller **50**, the robot controller **60**, the robot **70**, and the self-movable robot **80** correspond to industrial devices. The industrial device is not limited these examples and may be any type of device. For example, the industrial device may be a machine tool, a transport apparatus, a motor controller, or a programmable logic controller (PLC). For example, the industrial device may be a sensor such as a motor encoder, an I/O device, or a vision camera.

The job is a physical operation performed by the industrial device, and may also be referred to as a process. For example, the job may be process, detection, transport, or inspection of a job object. The job object is a so-called a work, and is, for example, a component of an automobile or a motorcycle, an electric product, a material of ceramics or resin, or a food. For example, the job object is placed on a transport apparatus, such as a belt conveyer, to be moved and

processed. Further, for example, the job object is grasped by the robot **70** or the self-movable robot **80** and processed.

For example, the scheduling device **10** may be a server computer or a personal computer. The scheduling device **10** includes a CPU **11**, a storage unit **12**, and a communication unit **13**. The CPU **11** is an example of a configuration called a circuitry, and includes at least one processor, for example. The storage unit **12** includes a RAM, an EEPROM, and a hard disk. The storage unit **12** stores programs and data. The CPU **11** performs processing based on the programs and data. The communication unit **13** includes at least one of a communication interface for wired communication and a communication interface for wireless communication. The communication unit **13** may include both of these or may include only one of them.

The instruction device **20** is a computer for instructing a specific job based on a schedule managed by the scheduling device **10**. For example, the instruction device **20** generates a program necessary for each job based on a rough schedule received from the scheduling device **10**. In other words, the instruction device **20** embodies the rough instruction received from the scheduling device **10** and gives a specific instruction to each cell.

For example, the instruction device **20** may be a server computer or a personal computer. The instruction device **20** includes a CPU **21**, a storage unit **22**, and a communication unit **23**. The physical configurations of the CPU **21**, the storage unit **22**, and the communication unit **23** may be the same as those of the CPU **11**, the storage unit **12**, and the communication unit **13**, respectively.

The information collecting device **30** is a computer that collects various types of information in the production system S. For example, the information collecting device **30** obtains trace data in which results of operations of the industrial devices belonging to the respective cells are stored in time series. The trace data indicates time-series changes in physical quantities detected by, for example, a sensor **71** to be described later. For example, the information collecting device **30** may obtain an image or video captured by a camera **72**. Further, the information collecting device **30** may analyze the information collected by itself. For example, the information collecting device **30** may analyze a cause of an alarm, or evaluate quality of a job object or a final product based on the collected information.

For example, the information collecting device **30** may be a server computer or a personal computer. The information collecting device **30** includes a CPU **31**, a storage unit **32**, and a communication unit **33**. The physical configurations of the CPU **31**, the storage unit **32**, and the communication unit **33** may be the same as those of the CPU **11**, the storage unit **12**, and the communication unit **13**, respectively.

The simulation device **40** is a computer for simulating the job of the entire production system S. For example, the simulation device **40** inputs instructions entered for each industrial device into a known simulator to obtain simulation results of the job. The simulation device **40** compares the actual operation results obtained by the information collecting device **30** with the simulation results. The simulation device **40** determines whether these results are deviated, and if they are deviated, changes the program or notifies an administrator. The deviation means that results as simulated (expected results) are not obtained.

For example, the simulation device **40** is a server computer or a personal computer. The simulator **40** includes a CPU **41**, a storage unit **42**, and a communication unit **43**. The physical configurations of the CPU **41**, the storage unit **42**, and the communication unit **43** may be the same as those of the CPU **11**, the storage unit **12**, and the communication unit **13**, respectively.

The cell controller **50** is an industrial device that controls a cell. In this embodiment, a case will be described in which one cell controller **50** is included in each cell, although a plurality of cell controllers **50** may be included in each cell. In addition, the cell may include a higher-level industrial device than the cell controller **50**. The cell controller **50** controls the industrial device belonging to itself. When a self-movable robot **80** arrives at the cell and is connected to the cell controller **50**, the cell controller **50** controls the self-movable robot **80**. When the self-movable robot **80** leaves the cell, the self-movable robot **80** is removed from the control of the cell controller **50**.

For example, the cell controller **50** includes a CPU **51**, a storage unit **52**, and a communication unit **53**. The physical configurations of the CPU **51**, the storage unit **52**, and the communication unit **53** may be the same as those of the CPU **11**, the storage unit **12**, and the communication unit **13**, respectively.

The robot controller **60** is an industrial device for controlling the robot **70**. For example, the robot controller **60** controls the power to the motor in the robot **70** to move a robot arm or open and close a robot hand based on an instruction from the cell controller **50**. The robot **70** of the present embodiment is a fixed type, and the robot arm and the robot hand move but the robot **70** itself does not move.

For example, the cell includes a sensor **71**, a camera **72**, and a communication device **73** in addition to the robot **70**. The sensor **71** may be any sensor capable of detecting a physical quantity, for example, a motor encoder, a torque sensor, a temperature sensor, a motion sensor, or a pressure-sensitive sensor. FIG. **1** shows only one sensor **71**, although the cell may include a plurality of sensors **71**. The data obtained by the sensor **71** may also be referred to as sensing data.

The camera **72** is a camera for capturing a state of the cell. The camera **72** is utilized in place of visual confirmation by a human and is also referred to as a vision camera (vision sensor). For example, the camera **72** captures each of the robot **70** and the job object in the cell and generates an image or video. For example, the camera **72** transmits the captured image or video to other devices such as the information collecting device **30**, the cell controller **50**, and the robot controller **60**. If the camera **72** is provided with an image analyzing function, the camera **72** transmits the analysis result. The analysis result may be the current state of the robot **70** or the current state of the job object.

The communication device **73** is a communication interface for wired communication. The communication device **73** is connected to a self-movable robot **80** that has arrived at its cell. For example, the self-movable robot **80** approaches the communication device **73** of the cell, which is the destination, and connects a wired communication unit **85**B described later to the communication device **73**. Thereby, wired communication between the self-movable robot **80** and the destination cell is established. The communication device **73** may use a device of any communication standard, for example, a dedicated communication standard such as IO-Link (registered trademark) or a common communication standard such as Ethernet (registered trademark). For example, the communication device **73** may have a communication connector into which a communication cable is insertable, or may implement pseudo wired communication using infrared rays (not insertion-type communication but contact-type wired communication).

The self-movable robot **80** is a self-movable industrial device. The self-movable means running by its own power. The self-movable industrial device may be any industrial device having a self-movable function, and is not limited to the self-movable robot **80**. For example, the self-movable industrial device may be a self-movable machine tool, a self-movable transport device, a self-movable motor controller, a self-movable PLC, a self-movable sensor, or a self-movable camera.

In the present embodiment, the self-movable robot **80** may freely move to any location. For example, the self-movable robot **80** moves between one cell and another cell. The self-movable robot **80** is not limited to the movement between the cells, and may move within the cell or may move to a location that is not related to the cell. In the present embodiment, a case will be described in which the self-movable robot **80** moves freely on a floor, although the self-movable robot **80** may move on a rail. For example, rails may be disposed between the cells, and the self-movable robot **80** may move between the cells by moving on the rails.

FIG. **2** is a diagram illustrating an example of a detailed configuration of the self-movable robot **80**. As shown in FIG. **2**, the self-movable robot **80** includes a robot unit **81** and an automated guided vehicle (AGV) unit **89**. The self-movable robot **80** may not be divided into the robot unit **81** and the AGV unit **89**, and they may be integrated and may not be distinguished from each other.

The robot unit **81** performs jobs in the cell in which the self-movable robot **80** has moved. For example, the robot unit **81** includes a robot controller **82**, a robot **86**, a sensor **87**, and a camera **88**. In FIG. **2**, the number of each of them is one, although each of them may be plural. The robot unit **81** may include other devices. For example, the robot unit **81** may include a spare end effector or a battery.

The physical configurations of the robot controller **82**, the robot **86**, the sensor **87**, and the camera **88** may be the same as those of the robot controller **60**, the robot **70**, the sensor **71**, and the camera **72**, respectively. The camera **88** is used not only for detecting a job object but also for detecting the communication device **73**.

For example, the robot controller **82** includes a CPU **83**, a storage unit **84**, and a communication unit **85**. The physical configurations of the CPU **83**, the storage unit **84**, and the communication unit **85** may be the same as those of the CPU **11**, the storage unit **12**, and the communication unit **13**, respectively.

The robot controller **82** may not be mounted on the self-movable robot **80**. In this case, the cell controller **50** may be connected to the robot controller **82** for the self-movable robot **80**, and when the self-movable robot **80** arrives at the cell, the robot controller **82** may control the robot **86** mounted on the self-movable robot **80**. If the robot controller **82** is not mounted on the self-movable robot **80**, the self-movable robot **80** can be reduced in weight.

In this embodiment, wireless communication is used while the self-movable robot **80** is moving, and switched to wired communication when the self-movable robot **80** arrives at the cell. As such, the job performed after the self-movable robot **80** arrives at the cell can be synchronized with data in a fine control cycle not by using wireless communication having insufficient reliability, immediacy, and throughput, but by using wired communication in which these are sufficiently secured. For example, the communication unit **85** includes a wireless communication unit **85**A, which is a communication interface for wireless communication, and a wired communication unit **85**B, which is a communication interface for wired communication.

The wireless communication unit **85**A includes, for example, a communication card and an antenna for wireless communication. The wireless communication unit **85**A may use any communication standard, for example, wireless LAN, WiFi (registered trademark), or Bluetooth (registered trademark). The wired communication unit **85**B includes, for example, a communication card and a connector for wired communication. The wired communication unit **85**B may also use any communication standard, although in this embodiment, wired communication is implemented by using the communication device **73** in the cell, and thus the wired communication unit **85**B uses the same communication standard as the communication device **73**. This communication standard is as described above.

The AGV unit **89** is a so-called automatic guided vehicle or a carriage. For example, the AGV unit **89** includes an AGV controller **90**, a sensor **94**, a camera **95**, a motor **96**, tires **97**, and a battery **98**. In FIG. **2**, the number of each of them is one, although each of them may be plural.

The AGV controller **90** is a computer that controls movement of the self-movable robot **80**. The AGV controller **90** controls the movement of the self-movable robot **80** based on a predetermined movement path. The movement control itself of the self-movable robot **80** may use various known methods, for example, a self-movable control algorithm employed in a cleaning robot, and an automatic driving technique employed in an automobile. Further, for example, the movement control of the self-movable robot **80** may be implemented by an open source called ROS.

For example, the AGV controller **90** is a personal computer, a tablet terminal, or a smart phone. For example, the AGV controller **90** includes a CPU **91**, a storage unit **92**, and a communication unit **93**. The physical configurations of the CPU **91**, the storage unit **92**, and the communication unit **93** may be the same as those of the CPU **11**, the storage unit **12**, and the communication unit **13**, respectively.

The sensor **94** detects a status around the self-movable robot **80**. For example, the sensor **94** may be a depth sensor, ultrasound sensor, infrared sensor, object detection sensor, indoor GPS sensor, beacon sensor, RFID sensor, geomagnetic sensor, gyro-sensor, or motion sensor. The camera **95** is a camera for capturing a view around the self-movable robot **80**. The camera **95** may have the physical configuration similar to that of the cameras **72** and **88**, and may be a so-called vision sensor.

For example, upon receiving a predetermined movement instruction from the instruction device **20**, the AGV controller **90** generates a movement path to the destination included in the movement instruction. The AGV controller **90** supplies power from the battery **98** to the motor **96** to control the rotation of the tires **97** so as to move along the generated movement path based on the information obtained from each of the sensor **94** and the camera **95**.

The AGV controller **90** may not be mounted on the self-movable robot **80**. In this case, the self-movable robot **80** may receive an instruction from another computer (e.g., instruction device **20**) and may move based on the instruction. For example, another computer having a function equivalent to that of the AGV controller **90** is disposed in the facility, and the self-movable robot **80** moves between the cells by communicating with the other computer. If the AGV controller **90** is not mounted on the self-movable robot **80**, the self-movable robot **80** can be reduced in weight.

Further, the program and data described as being stored in each of the scheduling device **10**, the instruction device **20**,

the information collecting device **30**, the simulation device **40**, the cell controller **50**, the robot controller **60**, and the self-movable robot **80** may be supplied via a network. Further, the hardware configuration of each device is not limited to the above example, and various types of hardware can be applied. For example, a reading unit (e.g., an optical disk drive or a memory card slot) for reading a computer-readable information storage medium or an input/output unit (e.g., a USB terminal) for directly connecting to an external device may be included. In this case, the program and data stored in the information storage medium may be supplied through the reading unit or the input/output unit. Further, an application specific integrated circuit called ASIC may also be included.

[1-2. Outline of Production System]

In this embodiment, the processing of the production system S will be described by taking an example of a case where so-called multi-product small-volume production is implemented. In the multi-product small-volume production, products produced in each cell changes fluidly, and thus the number of industrial devices required in each cell also changes fluidly. For example, only fixed-type robots **70** fixed to the cell are sufficient to perform jobs in a certain time period, but in other time periods, the fixed robots **70** alone may be insufficient.

In this regard, if the maximum number of fixed robots **70** required at a cell are disposed for all the cells, the job according to the schedule may be possible, but the cost in the production system S increases. That is, in a time zone in which the job can be done with fewer robots **70**, the robot **70** that does nothing is wasteful. As such, in the production system S, the self-movable robot **80** is moved to the cell as necessary so as to reduce the number of fixed robots **70**.

FIGS. **3** to **6** are diagrams illustrating examples of cells in the production system S. In these drawings, the number of cells is two for explanation, although the number of cells may be three or more. Further, the number of self-movable robot **80** is described as one, although the number of self-movable robots **80** may be two or more. As shown in FIG. **3**, the fixed robots **70**A to **70**C are disposed in a cell X, and the fixed robots **70**D and **70**E are disposed in a cell Y. In FIGS. **3** to **6**, other devices such as the instruction device **20** are omitted.

In the state of FIG. **3**, the self-movable robot **80** is located away from the cells X and Y and does not belong to any cell. For example, the self-movable robot **80** is connected to the instruction device **20** by wireless communication and stands by on the spot. The wireless communication may be implemented by at least one of the wireless communication unit **85**A of the robot controller **82** and the communication unit **93** of the AGV controller **90**. Both of them may be used for wireless communication, or only one of them may be used for wireless communication.

When the time at which the self-movable robot **80** moves to any of the cells arrives, the instruction device **20** transmits a movement instruction to the self-movable robot **80**. Assume that the movement instruction includes a specific position of the destination of the self-movable robot **80** in the cell. In this embodiment, the move robot **80** switches from wireless communication to wired communication upon arriving at the cell of the destination, and thus the position of the destination is close to the communication device **73** of the cell of the destination.

Here, a case where the self-movable robot **80** is instructed to move to the cell Y will be described as an example. When the self-movable robot **80** receives a movement instruction from the instruction device **20** to move to the cell Y, the AGV controller **90** generates a movement path to the cell Y. The AGV controller **90** controls the motor **96** so as to move on the generated movement path.

As shown in FIG. **4**, while moving toward the cell Y, the self-movable robot **80** downloads data necessary for the next job (job in the cell Y) from the instruction device **20** by wireless communication. The self-movable robot **80** records the downloaded data in the storage unit **84** of its robot controller **82**. This eliminates the need for the self-movable robot **80** to download the data after arriving at the cell Y.

When arriving at the vicinity of the communication device **73** of the cell Y, the self-movable robot **80** detects the communication device **73** using the sensor **87** and the camera **88**, and connects its wired communication unit **85**B to the communication device **73**. That is, a plug-in is performed. When they are connected to each other, the self-movable robot **80** switches from wireless communication to wired communication, and communicates with the cell controller **50** of the cell Y, for example. Upon establishing the wired communication connection, the self-movable robot **80** executes the processing necessary for the job in the cell Y. Examples of this processing include processing for synchronizing with the other robots **70**D and **70**E of the cell Y, and performing calibration of the self-movable robot **80**. The details of such processing will be described in the embodiment 2 and the modified examples.

The self-movable robot **80** has already downloaded the data necessary for the next job by the wireless communication while moving to the cell Y, and thus, when the above-described processing executed with the cell controller **50** is completed, the job in the cell Y can be immediately started. The self-movable robot **80** performs the job in the cell Y based on the downloaded data and the instruction received from the cell controller **50** by the wired communication.

When the job in the cell Y is completed, the self-movable robot **80** disconnects the communication device **73** of the cell Y and deletes the downloaded data. The data may be held without being deleted. When leaving the cell Y, the self-movable robot **80** disconnects the wired communication to switch to the wireless communication. Upon establishing the wireless communication with the instruction device **20**, the self-movable robot **80** waits for the next movement instruction. The self-movable robot **80** may stay on the spot or may move away from the cell Y.

Here, a case where movement to the cell X is instructed will be described as an example. As shown in FIG. **5**, when the self-movable robot **80** receives a movement instruction from the instruction device **20**, the AGV controller **90** generates a movement path, and the self-movable robot starts moving toward the cell X. As shown in FIG. **6**, while moving toward the cell X, the self-movable robot **80** downloads data necessary for the job in the cell X from the instruction device **20**. This eliminates the need for the self-movable robot **80** to download the data after arriving at the cell X.

When arriving at the vicinity of the communication device **73** of the cell X, the self-movable robot **80** detects the communication device **73** using the sensor **87** and the camera **88**, and connects its wired communication unit **85**B to the communication device **73**. Thereafter, the self-movable robot **80** executes the same procedure as that in the case of arriving at the cell Y, and starts the job in the cell X. The self-movable robot **80** moves according to the schedule and executes the job until all the job for the day is completed. The self-movable robot **80** is not limited to move between the cells, and may move to a predetermined standby location

for the purpose of charging, for example. Such movement is also scheduled by the scheduling device **10**.

As described above, the production system S of the present embodiment causes the self-movable robot **80** to prepare for the next job before the self-movable robot **80** arrives at the next cell, thereby causing the next job to be started earlier and improving the production efficiency in the production system S. In the following, the detailed configuration of the production system S will be described.

[1-3. Functions Implemented in Production System]

FIG. **7** is a functional block diagram showing functions implemented in the production system S. Thereafter, functions implemented in each of the scheduling device **10**, the instruction device **20**, the information collecting device **30**, the simulation device **40**, the cell controller **50**, the robot controller **60**, and the self-movable robot **80** will be described.

[1-3-1. Functions Implemented in Scheduling Device]

In the scheduling device **10**, a data storage unit **100** and a schedule control unit **101** are implemented. The data storage unit **100** is implemented mainly by the storage unit **12**, and the schedule control unit **101** is implemented mainly by the CPU **11**.

[Data Storage Unit]

The data storage unit **100** stores schedule data relating to a schedule of the entire production system S. FIG. **8** is a diagram showing an example of data storage of the schedule data. As shown in FIG. **8**, the schedule data stores job order, job ID, cell ID, industrial device ID, and content of the job. The job order is the order of the job in one day. The job ID is an ID that uniquely identifies the job. The cell ID is an ID that uniquely identifies a cell. The industrial device ID is an ID for uniquely identifying an industrial device. The content of the job is the job to be performed by the industrial device indicated by the industrial device ID. As mentioned above, in this embodiment, the job is scheduled roughly, and thus the content of the job stored in the schedule data is rough. The schedule data is generated by the administrator of the production system S.

[Schedule Control Unit]

The schedule control unit **101** controls the schedule of the production system S based on the schedule data. For example, when a certain job order arrives, the schedule control unit **101** transmits a cell ID, an industrial device ID, and the job content of such job to the instruction device **20**. Further, for example, upon receiving a completion notification of the currently performed the job from the instruction device **20**, the schedule control unit **101** refers to the schedule data to specify the job in the next job order, and obtains the cell ID, the industrial device ID, and the content of the job. The schedule control unit **101** transmits the obtained information to the instruction device **20**. Thereafter, the schedule control unit **101** instructs the instruction device **20** about the job in accordance with the schedule defined in the schedule data until all the job for the day is completed.

[1-3-2. Functions Implemented in Instruction Device]

In the instruction device **20**, a data storage unit **200**, an instruction unit **201**, and a receiving unit **202** are implemented. The data storage unit **200** is implemented mainly by the storage unit **22**, and each of the instruction unit **201** and the receiving unit **202** is implemented mainly by the CPU **21**.

[Data Storage Unit]

The data storage unit **200** stores data necessary for various instructions to the industrial devices. The instruction device **20** mainly instructs the self-movable robot **80** to move and instructs the cell controller **50** to perform a specific job, and thus the data storage unit **200** stores data required for these instructions. For example, the data storage unit **200** stores position information of each cell and map information of the facilities of the production system S. In this embodiment, the self-movable robot **80** move to the vicinity of the communication device **73** in the cell, and thus the data storage unit **200** stores the position information of the communication devices **73** in the respective cells.

For example, the data storage unit **200** stores a job program and setting data to be transmitted to the cell controller **50** and the self-movable robot **80**. The job program is a program in which the procedure of the job is defined. In the job program, the procedure from the start to the end of the job is indicated in time series. The job program may be generated in any language, such as a ladder language and a robotic language. In this embodiment, the instruction device **20** generates the job program, although the job program may be stored in the instruction device **20** in advance. The job program itself may be generated by a known method.

The setting data relates to the setting of the job content. For example, the setting data is a parameter such as a torque value. The teaching data in the robot control is also an example of the setting data. As in the modified example to be described later, the setting data may be adjusted by the position and the orientation of the self-movable robot **80** after the arrival.

[Instruction Unit]

The instruction unit **201** transmits an instruction to each industrial device. For example, the instruction unit **201** transmits a movement instruction including a position of a destination to the self-movable robot **80**. Further, for example, the instruction unit **201** transmits a job program and setting data stored in the data storage unit **200** as a job instruction to the cell controller **50** and the self-movable robot **80**. In this embodiment, when receiving a job completion notification, the instruction unit **201** instructs the self-movable robot **80** to move to the next location. The instruction unit **201** instructs the self-movable robot **80** to move to the next location on condition that the job completion notification is received. When the job completion notification is not received, the instruction unit **201** does not instruct the self-movable robot **80** to move to the next location, and instructs the self-movable robot **80** to move to the next location in response to the reception of the job completion notification.

[Receiving Unit]

The receiving unit **202** receives a predetermined job completion notification. The job completion notification is a notification indicating that the job has been completed, and is performed by transmitting data in a predetermined format. For example, the job completion notification includes information such as a job ID of the industrial device that has completed the job, and a job ID of the completed job. In this embodiment, the receiving unit **202** receives the job completion notification from the cell controller **50**, although the receiving unit **202** may receive the job completion notification from other devices such as the robot controllers **60** and **82**.

[1-3-3. Functions Implemented in Information Collecting Device]

In the information collecting device **30**, a data storage unit **300** and an information collecting unit **301** are implemented. The data storage unit **300** is mainly implemented by the storage unit **32**, and the information collecting unit **301** is mainly implemented by the CPU **31**.

[Data Storage Unit]

The data storage unit **300** stores various types of data relating to the production system S. For example, the data storage unit **300** stores trace data generated by each of the robot controllers **60** and **82**. For example, the data storage unit **300** stores an image or video captured by the camera **72**. For example, the data storage unit **300** stores a state of the industrial device and a state of a job object that are obtained by analyzing the image or the video. For example, the data storage unit **300** stores information transmitted by the self-movable robot **80** when the self-movable robot **80** arrives at each cell.

[Information Collecting Unit]

The information collecting unit **301** collects various types of data relating to the production system S. For example, the information collecting unit **301** collects trace data and an image or video captured by the camera **72** from the cell controller **50**. For example, when image analysis is performed by the cell controller **50**, the information collecting unit **301** collects an analysis result of the image analysis (a state of the industrial device or a state of the job object) from the cell controller **50**. For example, the information collecting unit **301** collects information transmitted from the self-movable robot **80** when the self-movable robot **80** arrives at each cell.

[1-3-4. Functions Implemented in Simulation Device]

In the simulation device **40**, a data storage unit **400** and a simulation executing unit **401** are implemented. The data storage unit **400** is implemented mainly by the storage unit **42**, and the simulation executing unit **401** is implemented mainly by the CPU **41**.

[Data Storage Unit]

The data storage unit **400** stores data required for executing simulations. For example, the data storage unit **400** stores simulators. The simulator is a program developed for the simulation of the industrial device. Various well-known simulators may be used for the simulator itself, and for example, a robot simulator provided by the industrial device manufacturer may be used. Further, for example, the data storage unit **400** stores simulation results by the simulator.

[Simulation Executing Unit]

The simulation executing unit **401** executes a simulation. For example, the simulation executing unit **401** obtains the content of the instruction of the job from the instruction device **20**, the information collecting device **30**, or the cell controller **50**. The simulation executing unit **401** inputs the obtained instruction content to the simulator and obtains the simulation result. For example, the state of the industrial device or the state of the job object may be obtained as the simulation result. The simulation executing unit **401** compares the simulation result with the trace data stored in the information collecting device **30**, for example, to verify the degree of deviation of them.

[1-3-5. Functions Implemented in Cell Controller]

In the cell controller **50**, a data storage unit **500**, a cell control unit **501**, and a transmitting unit **502** are implemented. The data storage unit **500** is mainly implemented by the storage unit **52**, and the cell control unit **501** and the transmitting unit **502** are mainly implemented by the CPU **51**.

[Data Storage Unit]

The data storage unit **500** stores data required for controlling the industrial devices in the cell (i.e., industrial devices to be managed by the cell controller **50**). For example, the data storage unit **500** stores the job program and the setting data received from the instruction device **20**. Further, for example, the data storage unit **500** stores data in which various types of information of the industrial devices in the cell is stored. Such information includes industrial device IDs, IP addresses, serial numbers or model numbers of the industrial devices in the cell, for example. Further, for example, the data storage unit **500** may store the job program and the setting data generated in advance by the administrator instead of the job program and the setting data received from the instruction device **20**.

[Cell Control Unit]

The cell control unit **501** controls the industrial devices in the cell based on the data stored in the data storage unit **500**. For example, the cell control unit **501** executes a job program and determines an instruction to the robot controller **60** by using the setting data as an argument. The cell control unit **501** sends the instruction to the robot controller **60**. The cell control unit **501** receives the response from the robot controller **60** and records the response in the data storage unit **500** in time series.

When the self-movable robot **80** arrives at the cell and starts the job, the cell control unit **501** transmits an instruction to the robot controller **82** of the self-movable robot **80** similarly to the robot controller **60** that controls the fixed robot **70**. The cell control unit **501** receives responses and trace data from the robot controllers **60** and **82**. For example, the instruction or the response of the job content is performed by synchronous communication, and transmission of the trace data is performed by asynchronous communication. The communication may be performed by periodic communication, or the cycle may not be particularly determined.

The cell control unit **501** transmits the trace data, for example, collected from the robot controller **60** and the self-movable robot **80** to the information collecting device **30**. The timing at which the cell control unit **501** transmits the trace data to the information collecting device **30** may be freely determined. For example, the data may be uploaded one by one to the information collecting device **30**, or the administrator may upload the data by a predetermined operation. Further, for example, the trace data may be transmitted directly from each of the robot controller **60** and the self-movable robot **80** to the information collecting device **30**.

[Transmitting Unit]

When the current job of the robots **70** and **86** is completed, the transmitting unit **502** transmits a predetermined job completion notification to the instruction device **20**. The transmitting unit **502** transmits the job completion notification to the instruction device **20** on condition that the current job of the robots **70** and **86** is completed. When the current job of the robots **70** and **86** is not completed, the transmitting unit **502** does not transmit the job completion notification to the instruction device **20**, and transmits the job completion notification to the instruction device **20** in response to completion of the current job of the robots **70** and **86**.

[1-3-6. Functions Implemented in Robot Controller]

In the robot controller **60**, a data storage unit **600** and a job control unit **601** are implemented. The data storage unit is mainly implemented by the storage unit **62**, and the job control unit **601** is mainly implemented by the CPU **61**.

[Data Storage Unit]

The data storage unit **600** stores data required for controlling the robot **70**. For example, the data storage unit **600** stores the job program and setting data received from the cell controller **50**. Further, for example, the data storage unit **600** may store a job program and setting data generated by the administrator in advance instead of the program and data

received from the cell controller **50**. For example, the data storage unit **600** stores the tracing data prior to be transmitted.

[Job Control Unit]

The job control unit **601** controls the robot **70** based on the data stored in the data storage unit **600**. For example, the job control unit **601** executes the job program and uses the setting data as an argument to control the voltage to the motor in the robot **70** so that the robot **70** performs the desired movement. When completing the instruction from the robot controller **60**, the job control unit **601** transmits a response to the cell controller **50**.

[1-3-7. Functions Implemented in Self-Movable Robot]

As shown in FIG. **7**, in the self-movable robot **80**, a data storage unit **800**, a movement control unit **801**, a communication control unit **802**, a preparation control unit **803**, and a job control unit **804** are implemented.

[Data Storage Unit]

The data storage unit **800** stores the data required for moving to the cell to perform a job. For example, the data storage unit **800** includes a first data storage unit **800**A and a second data storage unit **800**B.

The first data storage unit **800**A is implemented mainly by the storage unit **84** of the robot controller **82**. The first data storage unit **800**A stores data required for the job after arriving at the cell. In this embodiment, such data is downloaded while moving, although the data may be stored in the first data storage unit **800**A in advance. In this embodiment, as an example of such data, a job program and setting data will be described. As described above, each of the job program and the setting data is generated by the instruction device **20**. For example, the first data storage unit **800**A may store the trace data in accordance with the job of the self-movable robot **80**.

The second data storage unit **800**B is implemented mainly by the storage unit **92** of the AGV controller **90**. The second data storage unit **800**B stores the data required to move to the cell. In this embodiment, such data is generated by the movement control unit **801** to be described later, although the data may be received from the instruction device **20** or stored in the second data storage unit **800**B in advance. The movement path data will be described as an example of such data. The second data storage unit **800**B also stores a path search algorithm for generating movement path data.

The movement path is data indicating a path from the current position of the self-movable robot **80** to the destination. The movement path data indicates positions to which the self-movable robot **80** moves in time series. For example, the movement path data is indicated by coordinates on a map indicating facilities such as a factory. Assume that the map data is stored in the second data storage unit **800**B in advance. The movement path data may not be shown on the map.

[Movement Control Unit]

The movement control unit **801** is implemented mainly by the CPU **91** of the AGV controller **90**. The movement control unit **801** controls movement of the self-movable robot **80**. In the present embodiment, the movement instruction is transmitted by the instruction device **20**, and thus the movement control unit **801** controls the movement of the self-movable robot **80** based on the position of the destination included in the movement instruction. In this embodiment, the destination is the next cell, and thus the movement control unit **801** controls the movement of the self-movable robot based on the location of the next cell included in the moving instruction. To control the movement means to control at least one of the moving direction and the moving speed.

For example, the movement control unit **801** obtains the current position based on at least one of a communication result of the communication unit **93**, a detection signal of the sensor **94**, and an image or video captured by the camera **95**. The detection method of the current position may use a known method, for example, a position detection method used in indoor positioning. The detection method of the current position may use a method of detecting marks disposed indoors with images, a beacon positioning method, a positioning method by RFID, a positioning method by ultrasonic waves, a positioning method by geomagnetism, or a positioning method by wireless communication.

The movement control unit **801** inputs the current position and the destination into the path search algorithm and generates movement path data. The path search algorithm itself can use known techniques, for example, Dijkstra's algorithm and A-star algorithm. The movement control unit **801** controls the movement of the self-movable robot **80** based on the movement path data. For example, the movement control unit **801** obtains the current position of the self-movable robot **80** by the method described above, and moves the self-movable robot **80** so that the current position passes the movement path indicated by the movement path data. The movement control unit **801** repeats obtaining the current position and controlling the movement of the self-movable robot **80** until the self-movable robot **80** arrives at the next cell that is the last point on the moving path.

[Communication Control Unit]

The communication control unit **802** is mainly implemented by the CPU **83** of the robot controller **82**. The communication control unit **802** controls the communication of the self-movable robot **80**. In this embodiment, the communication control unit **802** controls the self-movable robot **80** to perform wireless communication while the self-movable robot **80** is moving toward the next location, and controls the self-movable robot **80** to perform wire communication via the communication device when the self-movable robot **80** arrives at the next location.

The next location is the destination of the self-movable robot **80**. In this embodiment, the self-movable robot **80** moves between the cells, and thus the next cell as the destination corresponds to the next location. As such, in this embodiment, the next cell or the destination can be replaced with the next location. If the self-movable robot **80** moves to a different location within the same cell, the next location means the different location in the same cell.

"While moving toward the next location" is the period of time until the self-movable robot **80** arrives at the next location, for example, during the movement of the self-movable robot **80**. The self-movable robot **80** does not need to continue to move, and may pause in the middle of the movement. The period of time in which the self-movable robot **80** pauses along the way is also included in the time of the movement to the next location. For example, while the self-movable robot **80** is moving, the communication control unit **802** uses the wireless communication unit **85**A to enable the self-movable robot **80** to communicate wirelessly. In this embodiment, the self-movable robot **80** communicates wirelessly with the instruction device **20**, although the self-movable robot **80** may communicate wirelessly with other devices such as the information collecting device **30** or the cell controller **50**.

When the self-movable robot **80** arrives at the next location, the communication control unit **802** connects the

wired communication unit **85**B to the communication device **73** disposed at such a location, and switches from the wireless communication to the wire communication. Assume that the arrival of the self-movable robot **80** is detected by the movement control unit **801**. For example, the communication control unit **802** turns off the wireless communication unit **85**A and moves the wired communication unit **85**B to be closer to the communication device **73**.

For example, the communication control unit **802** specifies a specific position of the communication device **73** based on at least one of a communication result of the wireless communication unit **85**A, a detected signal of the sensor **87**, and an image or video captured by the camera **88**. The communication control unit **802** moves the wired communication unit **85**B so as to be closer to the specified position of the communication device **73**. The wired communication unit **85**B may be moved by controlling the motor in the robot unit **81** in the same manner as the control of the robot **86**. The wired communication unit **85**B may be moved by moving the self-movable robot **80** itself by the control of the AGV controller **90**.

For example, in a case of the contact-type communication device **73** using infra-red rays, the communication control unit **802** moves the wired communication unit **85**B until the wired communication unit **85**B is in contact with the communication device **73**. For example, in a case of the communication device **73** into which a communication cable is inserted, the communication control unit **802** moves the wired communication unit **85**B until the communication cable of the wired communication unit **85**B is inserted into the communication device **73**. The wired communication may be established in the procedure in accordance with the communication standard. In this embodiment, the communication partner in the wired communication is the cell controller **50**, although the communication partner in the wired communication may be other devices such as the instruction device **20**, the information collecting device **30**, and the robot controller **60**.

The communication control unit **802** switches from the wired communication to the wireless communication after the self-movable robot **80** completes the job. The timing of switching from the wired communication to the wireless communication may be any timing after the job is completed, for example, immediately after the job is completed or after a certain period of time has elapsed. Assume that the completion of the job of the self-movable robot **80** is detected by the job control unit **804**. The communication control unit **802** moves the wired communication unit **85**B so that the wired communication unit **85**B is disconnected from the communication device **73** and turns the wireless communication unit **85**A on. The wireless communication may also be established in the procedure in accordance with the communication standard.

In this embodiment, switching between the wired communication and the wireless communication is performed for the communication unit **85** of the robot controller **82**, and is not performed for the communication unit **93** of the AGV controller. As such, if the communication control unit **802** switches from the wireless communication to the wired communication, the wireless communication function of the AGV controller **90** is enabled, and as a whole, the self-movable robot **80** is capable of wireless communication with the instruction device **20**.

[Preparation Control Unit]

The preparation control unit **803** is mainly implemented by the CPU **83**. The preparation control unit **803** controls the self-movable robot **80** to prepare for the next job prior to arriving at the next location. In the present embodiment, the preparation control unit **803** is implemented by the self-movable robot **80**, although the preparation control unit **803** may be implemented by another computer such as the instruction device **20**, as in the modification examples described later.

"Prior to arriving at the next location" is any time before the self-movable robot **80** arrives at the next location. While this embodiment describes a case where moving to the next location corresponds to prior to arriving at the next location, it may correspond to other times, as in the modification examples described later. The next job is the job to be performed in the next location. In the present embodiment, specific content of the job is instructed from the instruction device **20**, and thus the job instructed from the instruction device **20** corresponds to the next job.

The preparation is preparation required for the next job. The preparation control unit **803** may prepare for the job electronically or physically. In this embodiment, a case will be described in which electronic preparation is made by downloading data, although the electronic preparation is not limited to downloading data. For example, the electronic preparation may be reading data from an information storage medium, activating a job program, expanding data into RAM, completing initialization, or activating the robot controller **82** or the sensor **87**.

In the present embodiment, the preparation control unit **803** includes a first preparation control unit **803**A and a download control unit **803**B. The first preparation control unit **803**A controls the self-movable robot **80** to prepare for the next job while the self-movable robot **80** is moving toward the next location. That is, the first preparation control unit **803**A controls the self-movable robot **80** to prepare for the next job while the self-movable robot **80** is moving. The first preparation control unit **803**A does not need to spend all the time during the movement of the self-movable robots **80** for preparation, and the preparation may be completed along the way.

The download control unit **803**B controls the self-movable robot **80** to download data to be used in the next job for preparation for the next location. In this embodiment, the download control unit **803**B downloads a job program and setting data from the instruction device **20**, and records the downloaded job program and setting data in the first data storage unit **800**A. The self-movable robot **80** communicates wirelessly while moving, and thus the download control unit **803**B downloads the data using wireless communication.

The preparation for the next job may be started at least before the self-movable robot **80** arrives at the next location, and the preparation does not have to be completed when the self-movable robot **80** arrives at the next location. For example, when the size of the job program and the setting data is large or the distance to the next location is short, the preparation may not be completed at the time of arrival at the next location. In this case, the preparation is continued after the arrival of the self-movable robot **80**. In this case, if the communication is switched to the wired communication, the download control unit **803**B may continue downloading using the wired communication. If not only the next job but also the next and a subsequent job (job two or more steps ahead) is determined, the preparation control unit **803** may prepare the next and the subsequent job.

[Job Control Unit]

The job control unit **804** is mainly implemented by the CPU **83**. The job control unit **804** controls the self-movable robot **80** to perform the next job when the self-movable robot **80** arrives at the next location and the preparation for

the next job is completed. In this embodiment, the job control unit **804** is implemented by the self-movable robot **80**, although the job control unit **804** may be implemented by other computers such as the cell controller **50**, as described later in the modified examples.

The job control unit **804** controls the self-movable robot **80** to perform the next job on condition that the self-movable robot **80** arrives at the next location and the preparation for the next job is completed. For example, the arrival at the next location is detected by the movement control unit **801**. For example, the job control unit **804** may determine whether the self-movable robot **80** arrives at the next location. In this embodiment, the robot controller **60** and the communication device **73** for wired communication are disposed at the next location, and thus the job control unit **804** may determine whether the wired connection with the robot controller **60** has been established. The establishment of the wired connection means that the self-movable robot **80** has arrived at the next location.

The arrival of the self-movable robot **80** may be determined by any method. For example, the arrival of the self-movable robot **80** may be determined based on at least one of content of the communication of the wireless communication unit **85**A, a signal detected by the sensor **94** of the AGV unit **89**, and an image or video captured by the camera **95**. In this case, a transmitter that emits a predetermined signal may be disposed or a predetermined mark may be arranged at the next location. Upon detecting the signal or the mark, the job control unit **804** determines that the self-movable robot **80** has arrived at the next location.

For example, the job control unit **804** determines whether the preparation for the next job is completed. The completion of the preparation may be determined by any method, for example, referring to the progress of the preparation by the preparation control unit **803** to determine whether the preparation is completed. The job control unit **804** controls the self-movable robotic **80** to perform the next job based on the preparation completed by the preparation control unit **803**. A known method may be used for the method of executing the job. For example, the cell controller **50** and the robot controller **82** of the self-movable robot **80** communicate with each other to execute the next job.

In this embodiment, the job control unit **804** includes a first job control unit **804**A. The first job control unit **804**A controls the self-movable robot **80** to perform the next job when the self-movable robot **80** arrives at the next location and completes downloading of the data. For example, the first job control unit **804**A determines whether the downloading of the data is completed by the download control unit **803**B. To complete downloading of the data means that to complete the preparation for the next job. The first job control unit **804**A performs the next job based on the downloaded data.

[1-4. Processing Executed in Production System]

FIGS. **9** to **11** are flow charts showing processing executed in the production system S. The processing shown in FIGS. **9** to **11** is executed by the CPUs **11**, **21**, **31**, **41**, **51**, **61**, **83**, and **91** operating in accordance with the programs respectively stored in the storage units **12**, **22**, **32**, **42**, **52**, **62**, **72**, **84**, and **92**. The processing described below is an example of processing executed by the functional block shown in FIG. **4**.

As shown in FIG. **9**, the scheduling device **10** transmits rough content of a job in the production plan to the instruction device **20** based on the schedule data stored in the storage unit **12** (S**1**). In S**1**, the scheduling device **10** transmits the cell ID, the industrial device ID, and the job content stored in the schedule data as the rough job content. The rough job content transmitted by the scheduling device **10** does not need to include the industrial device ID.

Upon receiving the rough job content, the instruction device **20** generates data necessary for the job (S**2**). In S**2**, the instruction device **20** generates the data to be used by at least one of the cell controller **50**, the robot controller **60**, and the self-movable robot **80**. In the present embodiment, such data is a job program and setting data. Assume that the algorithm for generating the data is stored in the storage unit **22** in advance. The data generation algorithm defines the relationship between the job content and the data generation method.

In S**3**, the instruction device **20** specifies a destination to transmit the data generated in S**2** and determines whether the self-movable robot **80** is included in the destination. This destination is the entity performing the next job. In this embodiment, a case will be described in which the industrial device indicated by the industrial device ID included in the rough job content received in S**2** is the destination, although the instruction device **20** may determine the destination to transmit the data by itself. For example, in a case where the industrial device ID is not included in the rough job content transmitted from the scheduling device **10**, the instruction device **20** may specify an appropriate industrial device based on the job content and determine the industrial device as a destination to transmit the data.

When it is determined that the self-movable robot **80** is not included in the destination to transmit the data (S**3**;N), the instruction device **20** transmits a job instruction including the data generated in S**2** to the cell controller **50** (S**4**). The job instruction instructs the start of the job, and is performed by transmitting data in a predetermined format.

Upon receiving the job instruction from the instruction device **20**, the cell controller **50** records the data included in the job instruction in the storage unit **52** (S**5**), and instructs the robot controller **60** of its cell to perform the job (S**6**). In S**6**, the robot controller **60** controls the robot **70** in response to the instruction from the cell controller **50**. Assume that the job program and the setting data are developed in each robot controller **60** between the cell controller **50** and the robot controller **60**, and processing such as IP address exchange is executed in advance.

The robot controller **60** executes the job based on the instruction from the cell controller **50** (S**7**). In S**7**, the robot controller **60** transmits the execution result of the job as a response to the cell controller **50**. Further, the robot controller **60** may transmit trace data based on the detection signal of the sensor **71** connected to the robot controller **60**. The cell controller **50** also receives a response from the robot controller **60**. The cell controller **50** also records the received trace data and the image or video captured by the camera **72** in the storage unit **52**. Assume that the data in the cell are synchronized and the time axes of the data are aligned with each other.

The cell controller **50** determines whether the job instructed by the instruction device **20** is completed (S**8**). If it is not determined that the job is completed (S**8**; N), the processing returns to S**6** and the job is continued. If it is determined that the job is completed (S**8**; Y), the cell controller **50** transmits a job completion notification to the instruction device **20** (S**9**).

Upon receiving the job completion notification from the cell controller **50**, the instruction device **20** transfers the job completion notification to the scheduling device **10** (S**10**). The processing of S**10** may be omitted. The instruction device **20** may notify the scheduling device **10** when a

predetermined number of jobs are completed. The instruction device **20** determines whether there is next job based on the rough job content received from the scheduling device **10** or the data generated in S**2** (S**11**). If it is determined that there is the next job (S**11**;Y), the processing proceeds to S**3**, and the destination of the data of the next job is referred.

In S**3**, if it is determined that the self-movable robot **80** is included in the destination of the data of the instruction device **20** (S**3**;Y), proceeding to FIG. **10**, the instruction device **20** transmits a job instruction including the data generated in S**2** to the cell controller **50** (S**12**), and transmits a movement instruction to the self-movable robot **80** (S**13**). The processing of S**12** is the same as the processing of S**4**. The movement instruction transmitted in S**13** is an instruction to move to the next location, and is performed by transmitting data in a predetermined format. Assume that the movement instruction includes information for identifying the location of the movement destination. As described above, the movement destination is a position in the vicinity of the communication device **73** of the next cell.

The processing of S**14** executed by the cell controller **50** is the same as the processing of S**5**. The cell controller **50** determines whether the self-movable robot **80** has arrived at its cell (S**15**). When it is not determined that the self-movable robot **80** has arrived (S**15**;N), the processing returns to S**15** again, and the arrival of the self-movable robot **80** is waited for.

Upon receiving the movement instruction, the self-movable robot **80** uses the AGV controller **90** to generate a movement path to the destination included in the movement instruction (S**16**). In S**16**, the self-movable robot **80** may generate a movement path based on a known path search algorithm. The movement path is generated so as not to interfere with the fixed robot **70** or other self-movable robot **80** from the current position of the self-movable robot **80** toward the destination.

The self-movable robot **80** controls the movement toward the next cell, which is the destination, based on the movement path generated in S**16** (S**17**). In S**17**, the self-movable robot **80** analyzes the surrounding state based on the detection signal of the sensor **94** and the image or video captured by the camera **95**. The self-movable robot **80** moves on the movement path by rotating the motor **96** based on the analysis result.

While moving toward the next cell, the self-movable robot **80** downloads the data generated in S**2** using the wireless communication unit **85**A from the instruction device **20** (S**18**). If the download is completed during the movement, the processing of S**18** is not executed.

The self-movable robot **80** determines whether the self-movable robot **80** has arrived at the next cell, which is the destination, based on at least one of communication content of the wireless communication unit **85**A, a detection signal of the sensor **94**, and an image or video captured by the camera **95** (S**19**). For example, a predetermined mark may be arranged in the vicinity of the communication device **73**, and when the self-movable robot **80** detects the mark, the self-movable robot **80** may be determined to have arrived at the next cell. If it is not determined that the self-movable robot **80** has arrived at the next cell (S**19**; N), the processing returns to S**17**, and the movement control by the self-movable robot **80** is continued.

If it is determined that self-movable robot **80** has arrived at the next cell (S**19**;Y), the self-movable robot **80** provides a wired connection between the communication device **73** of the cell and the wired communication unit **85**B of the self-movable robot **80** (S**20**). In S**20**, the self-movable robot **80** identifies the position of the communication device **73** and connects its own wired communication unit **85**B based on at least one of communication content of the wireless communication unit **85**A, a detected signal of the sensor **94**, and an image or video captured by the camera **95**. In the case of the contact-type communication device **73**, when the wired communication unit **85**B is in contact with the communication device **73**, these devices are connected by wired communication. The self-movable robot **80** establishes the wired communication with the cell controller **50** via the communication device **73**, and executes initial setting for performing the job in the cell at which the self-movable robot **80** arrives. As in the embodiment 2 described later, the self-movable robot **80** is capable of performing the job synchronously with the robot **70** of this cell.

When the wired communication with the self-movable robot **80** is established, if it is determined in S**15** that the self-movable robot **80** has arrived (S**15**;Y), the cell controller **50** instructs the job to each of the robot controller **60** and the self-movable robot (S**21**). Communication is then performed between the cell controller **50**, the robot controller **60**, and the self-movable robot **80**, and the job instructed from the instruction device **20** is executed (S**22**). The processing of S**22** is the same as the processing of S**7**. In the processing of S**22**, the robot controller **82** of the self-movable robot **80** is handled in the same way as the robot controller **60**.

The cell controller **50** determines whether the job instructed by the instruction device **20** is completed (S**23**). If it is not determined that the job is completed (S**23**;N), the processing returns to S**21**, and the job is continued. If it is determined that the operation is completed (S**23**;Y), the cell controller **50** transmits an instruction to the self-movable robot **80** to leave its cell (S**24**). The leaving instruction is an instruction to leave a cell, and is performed by transmitting data in a predetermined format. Subsequently, the cell controller **50** proceeds to the processing of S**9** shown in FIG. **9**, and transmits a job completion notification to the instruction device **20**.

Upon receiving the leaving instruction, the self-movable robot **80** disconnects the wired connection between the communication device **73** and its wired communication unit **85**B (S**25**), and switches to a wireless connection using its wireless communication unit **85**A (S**26**). In S**26**, the self-movable robot **80** specifies the position of the communication device **73** based on a detected signal of the sensor **94** and an image or video captured by the camera **95**, and disconnects its wired communication unit **85**B. In the case of the contact-type communication device **73**, the connection is disconnected by detaching the wired communication unit **85**B from the communication device **73**.

Referring to FIG. **11**, the cell controller **50** determines whether the information collection timing has arrived (S**27**). The information collection timing is a timing at which information such as trace data is provided to the information collecting device **30**. When it is not determined that the information collection timing has arrived (S**27**;N), the information such as the trace data is not transmitted. If it is determined that the information collection timing has arrived (S**27**;Y), the cell controller **50** transmits the information such as the trace data recorded in the storage unit **52** to the information collecting device **30** (S**28**).

Upon receiving the information such as the trace data, the information collecting device **30** records the data in the storage unit **32** (S**29**), and transmits a request to execute a simulation to the simulation device **40** (S**30**). The execution request is a request for executing a simulation based on the

information recorded in the storage unit **32**, and is performed by transmitting data in a predetermined format. The execution request includes the trace data to be simulated and content of the instruction at that time.

Upon receiving the execution request, the simulation device **40** executes a simulation (S**31**). In S**31**, the simulation device **40** inputs the instruction from the instruction device **20** to a simulator, and obtains a simulation result.

The simulation device **40** compares the simulation result with the actual job result indicated by the trace data, and determines whether the deviation between the results is equal to or greater than a threshold value (S**32**). If it is determined that the deviation is equal to or larger than the threshold value (S**32**;Y), the information collecting device **30** executes processing such as changing the job program (S**33**).

The processing described above is executed until there is no schedule for the next job. In S**11** shown in FIG. **9**, if it is not determined that there is a schedule for the next job (S**11**;N), all the job for the day has been completed, and this processing terminates.

The production system S of the embodiment 1 enables the self-movable robot **80** to start preparing for the next job before arriving at the next location, which serves to start the next job promptly and to improve the production efficiency in the production system S. For example, if the self-movable robot **80** arrives at a next location and then starts preparation for the next job, the robot controller **60** at the next location needs to wait until the preparation is completed. The production system S of the embodiment 1 eliminates or shortens such waiting time, thereby improving the production efficiency.

Further, in the production system S, the self-movable robot **80** is controlled to prepare for the next job while moving toward the next location, thereby preparing for the job at an earlier stage to effectively increase the production efficiency in the production system S.

Further, in the production system S, the self-movable robot **80** is controlled to download data to be used in the next job as a preparation for the next location. As such, even if the data to be used in the next job is not recorded in the self-movable robot **80**, the data can be downloaded at an earlier stage and the production efficiency in the production system S can be improved. Further, if the data of all the job performed by the self-movable robot **80** for the day is recorded in advance, the memory consumption increases, but the memory consumption can be reduced by downloading the data before the self-movable robot **80** arrives at the next location.

Further, in the production system S, while the self-movable robot **80** is moving toward the next location, the self-movable robot **80** provides wireless communication, and when the self-movable robot **80** arrives at the next location, the self-movable robot **80** provides wired communication through the communication device **73** for wired communication. This enables to provide a communication in a manner suitable to the situation at that time. For example, when the self-movable robot **80** performs the job in the next location, the job can be performed by stable wired communication. Further, for example, while moving toward the next location, the self-movable robot **80** can use wireless communication so as to prepare for the job at the next location. Further, for example, when the self-movable robot **80** uses wired communication while moving toward the next location, a cable may interfere with the movement, but switching to wireless communication during the movement can reduce the possibility that the movement of the self-movable robot **80** is interfered. Further, for example, by switching to the wired communication when the self-movable robot **80** starts the job, the time axis of the trace data can be aligned with other devices such as the cell controller **50**. In this way, it is possible to identify a point in time of individual states indicated by the trace data of the self-movable robot **80**.

Further, in the production system S, before the self-movable robot **80** having the AGV unit **89** and the robot **86** arrives at the next location, the self-movable robot **80** is controlled to prepare for the next job. This can improve the production efficiency in the production system S.

2. Embodiment 2

Next, another embodiment (hereinafter, embodiment 2) of the production system S will be described. As described in the embodiment 1, in the next cell to which the self-movable robot **80** is moved, the fixed robot **70** belonging to such a cell is disposed. In the job of the next location, if the self-movable robot **80** and the robot controller **60** are not operated in synchronization with each other, they may hinder the job by coming into contact with each other, for example. For this reason, the production system S of the embodiment 2 synchronizes the self-movable robot **80** and the robot controller **60** when the self-movable robots **80** arrives at the next location.

FIG. **12** is a functional block diagram of the embodiment 2. As shown in FIG. **12**, in the embodiment 2, a synchronization control unit **805** is implemented in the self-movable robot **80** in addition to the functions described in the embodiment 1. For example, the synchronization control unit **805** is implemented mainly by the CPU **83** of the robot controller **82**. The synchronization control unit **805** synchronizes the self-movable robot **80** and the robot controller **60** when the self-movable robot **80** arrives at the next location.

The synchronization is coordination between an operation of one industrial device and an operation of another industrial device. In other words, the synchronization is that an industrial device detects a state of another industrial device and operates in accordance with the state of another industrial device. The synchronization is also referred to as synchronous control, and may be implemented by synchronous communication. To wait until another industrial device becomes a predetermined state also corresponds to the synchronization.

The synchronization control unit **805** operates the self-movable robot **80** in response to the operation of the fixed robot **70**. For example, the synchronization control unit **805** operates the self-movable robot **80** so as to be a predetermined distance from the fixed robot **70** (so as not to contact the robot **70**). For example, the synchronization control unit **805** operates the self-movable robot **80** such that, when the fixed robot **70** holds a job object, the robot hand of the self-movable robot **80** approaches the job object. For example, the synchronization control unit **805** operates the self-movable robot **80** such that, when the self-movable robot **80** holds a job object, the job object approaches the fixed robot **70**.

For example, the synchronization control unit **805** includes an obtainment control unit **805**A. When the self-movable robot **80** arrives at the next location, the obtainment control unit **805**A controls the self-movable robot **80** to obtain at least one of information on a state of the robot **70** controlled by the robot controller **60**, information on a state of a job object at the next location, and detected information of a peripheral device at the next location.

The Information on the state of the robot **70** is information about at least one of the position, posture, orientation, and speed of the robot **70**. The job executed by the robot controller **60** that controls the robot **70** is also an example of information on the state of the robot **70**. For example, information detected by the sensor **71** or the camera **72** (sensing data, image, video) is also an example of information on the state of the robot **70**.

The information on the state of the job object is information about at least one of the shape, position, posture, orientation, and speed of the job object. This information is detected by the sensor **71** or the camera **72**. The peripheral device is a device other than the robot controller **60** and the robot **70**, and is, for example, at least one of the sensor **71** and the camera **72**. For example, the detection information of the peripheral device is a physical quantity detected by a temperature sensor or a torque sensor.

The information described above is information necessary for synchronization. The obtainment control unit **805**A may controls the self-movable robot **80** to obtain all of these pieces of information, or only one or two of these pieces of information. In this embodiment, the cell controller **50** transmits such information, although other devices, such as the information collecting device **30**, may transmit such information. The robot controller **60** also obtains information necessary for synchronization.

Assume that a program indicating the actions of the self-movable robots **80** corresponding to the above-described information is stored in the storage unit **84**. The program is necessary for the synchronization with the robot **70**. The program may be obtained using the wireless communication while moving, or using the wired communication after arriving at the cell. The self-movable robot **80** acts according to the obtained information based on the program, thereby synchronizing with the robot **70**.

For example, when a robot arm of the robot **86** of the self-movable robot **80** is in the vicinity of a robot arm of the other robot **70**, the self-movable robot **80** controls the robot **86** so as to move away from the robot arm of the robot **70**. For example, if the job object does not reach a predetermined state, the self-movable robot **80** waits until the job of the other robots **70** is completed. For example, the self-movable robot **80** may change its job according to the physical quantity detected by the sensor **71**. Further, for example, the self-movable robot **80** may change its job in accordance with the state of the job object detected by the camera **72** or the state of the other robots **70**.

According to the production system S of the embodiment 2, when the self-movable robot **80** arrives at the next location, the self-movable robot **80** and the robot controller **60** are synchronized, and the self-movable robot **80** is thereby synchronized with the robot controller **60**. This increases the production efficiency of the production system S. Further, the self-movable robot **80** and the robot controller **60** are synchronized, and this prevents them from interfering with each other by making a contact with each other during the job, for example.

Further, in the production system S, when the self-movable robot **80** arrives at the next location, the self-movable robot **80** obtains information about at least one of the state of the robot controller **60**, the state of the job object at the next location, and the information detected by the peripheral device at the next location. This can improve the production efficiency of the production system S. For example, the state of the robot controller **60** is provided to the self-movable robot **80**, which prevents the self-movable robot **80** from becoming an obstacle to the job of the robot controller **60**. Further, for example, the state of the job object in the next location is provided to the self-movable robot **80**, which serves to increase the job accuracy of the self-movable robot **80** in the next location. Further, for example, the detection information of the peripheral device in the next place is provided to the self-movable robot **80**, which serves to improve the job efficiency in the next location.

The production system S of the embodiment 2 may not have the functions of the embodiment 1. For example, the production system S may synchronize the self-movable robot **80** with the other robots **70** in the cell when the self-movable robot **80** arrives at the next cell without making the self-movable robot **80** to prepare during the movement as described in the embodiment 1. In this case, the self-movable robot **80** may prepare for the job in the next cell after arriving at the next cell.

3. Modification Examples

The present invention is not to be limited to the above described embodiments. The present invention can be changed as appropriate without departing from the spirit of the invention.

FIG. **13** is a functional block diagram of a modification example. As shown in FIG. **13**, in the modification example described below, a before/after preparation control unit **503**, a second preparation control unit **803**C, a third preparation control unit **803**D, amounting control unit **803**E, a fourth preparation control unit **803**F, a second job control unit **804**B, a determining unit **806**, a setting unit **807**, and a transmission control unit **808** are implemented in addition to the functions described in embodiment 1. In FIG. **13**, the synchronization control unit **805** described in the embodiment 2 is omitted, although the synchronization control unit **805** may also be implemented in the following modification examples.

(1) For example, the timing at which the self-movable robot **80** prepares for the next job is not limited to the time during the movement as described in the embodiments 1 and 2. In the examples of FIGS. **3** to **6**, the preparation for the job in the next cell X may be started when the self-movable robot **80** completes the job in the cell Y.

In the production system S of the present modification example, the determining unit **806** is implemented. The determining unit **806** is mainly implemented by the CPU **83**. The determining unit **806** determines whether the current job of the self-movable robot **80** is completed. The current job is the job in the cell where the self-movable robot **80** is currently positioned. The current job may be the job performed by the self-movable robot **80** in this cell, or the job of the entire cell. For example, in a case where the cell controller **50** transmits a predetermined job completion notification to the self-movable robot **80** when the current job is completed, the determining unit **806** determines whether the job completion notification is received. To receive the job completion notification means that the current job is completed.

The preparation control unit **803** of the present modification example includes the second preparation control unit **803**C. When it is determined that the current job is completed, the second preparation control unit **803**C controls the self-movable robot **80** to prepare for the next job. The second preparation control unit **803**C controls the self-movable robot **80** to prepare for the next job on condition that the current job is completed. The second preparation control unit **803**C controls the self-movable robot **80** not to prepare for the next job when the current job is not com-

pleted, and allows the self-movable robot **80** to prepare for the next job when the current job is completed. The method of preparation by the self-movable robots **80** is as described in the embodiment 1.

According to the modification example (1), when it is determined that the current job of the self-movable robot **80** is completed, the preparation of the next job is started at an earlier stage. This effectively increases the production efficiency in the production system S.

(2) Further, for example, in the examples of FIGS. **3** to **6**, when the self-movable robot **80** completes the job in the cell Y and is instructed to move toward the next cell X, the preparation of the next job may be started.

The preparation control unit **803** of this modification example includes the third preparation control unit **803**D. The third preparation control unit **803**D controls the self-movable robot **80** to prepare for the next job when the self-movable robot **80** is instructed to move to the next location. The third preparation control unit **803**D controls the self-movable robot **80** to prepare for the next job on condition that the self-movable robot **80** is instructed to move to the next location. The third preparation control unit **803**D controls the self-movable robot **80** not to prepare for the next job when the movement to the next location is not instructed, and allows the self-movable robot **80** to prepare for the next job when the movement to the next location is instructed. The method of preparation by the self-movable robots **80** is as described in the embodiment 1.

According to the modification example (2), when the movement to the next location is instructed, the self-movable robots **80** is allowed to prepare for the next job. This enables preparing for the job at an earlier stage, and effectively increasing the production efficiency in the production system S.

(3) For example, in the embodiments 1 and 2, downloading of data has been described as an example of preparation of the self-movable robots **80**, although the preparation may be physical preparation as described above. For example, when the robot hand of the robot **86** of the self-movable robot **80** is detachable, the robot hand may be replaced with a robot hand required in the next job as a preparation for the next job.

The preparation control unit **803** of the modification example includes the mounting control unit **803**E. The mounting control unit **803**E controls the self-movable robot **80** to mount a device to be used in the next job for preparation for the next location. The device may be any device that can be mounted on the self-movable robot **80** and can be used in the job. For example, the device is a so-called end effector. The device may be any type of device and is not limited to a robot hand. For example, the device may be a tool such as a soldering iron, a machine tool, a sensor, or a camera.

The mounting itself of the device may be implemented by various methods. For example, the mounting control unit **803**E may detect a device to be mounted by the sensor **87** or the camera **88**, and mount the device at a predetermined position, such as the distal end of the robot **86**. The device may be disposed on the cart of the self-movable robot **80**, for example, or at a predetermined location in the facility to be picked up by the self-movable robot **80**. For example, the mounting control unit **803**E removes the device currently mounted on the robot **86**, and mounts a device to be used in a subsequent operation on the robot **86**. The removed device may be disposed on the cart of the self-movable robot **80**, for example, or disposed at a predetermined location to which the self-movable robot **80** is moved.

The job control unit **804** of this modification example includes the second job control unit **804**B. The second job control unit **804**B controls the self-movable robot **80** to perform the next job when the self-movable robot **80** arrives at the next location and the device is mounted already. The second job control unit **804**B controls the self-movable robot **80** to perform the next job on condition that the self-movable robot **80** arrives at the next location and the device is mounted already. This modification example is different from the embodiments 1 and 2 only in that the mounted device can be used, and the method of controlling the job is as described in the embodiments 1 and 2.

According to the modification example (3), the self-movable robot **80** is provided with a device to be used in the next job as the preparation for the next location. As such, even if the self-movable robot **80** is not equipped with the device to be used in the next job, the self-movable robot **80** is provided with the device at an earlier stage, which serves to improve the production efficiency in the production system S.

(4) For example, before the self-movable robot **80** arrives at the next location, the robot controller **60** and the fixed robots **70** at such a location may prepare for the job. If the example of FIGS. **3** to **6**, before the self-movable robot **80** arrives at the cell Y, the robot controller **60** of the cell Y and the fixed robots **70**D and **70**E may prepare for the job. Similarly, before the self-movable robot **80** arrives at the cell X, the robot controller **60** of the cell X and the fixed robots **70**A to **70**C may prepare for the job.

The preparation control unit **803** of the present modification example includes the before/after preparation control unit **503**. The before/after preparation control unit **503** is implemented mainly by the CPU **51**. The before/after preparation control unit **503** controls the robot controller **60** to prepare for the job to be performed before or after the next job before the self-movable robot **80** arrives at the next location. The job to be performed before or after the next job is a pre-step or a post-step of the job to be performed by the self-movable robot **80** at the next location. In other words, the job to be performed before or after the next job is the job performed by the fixed robot **70** in cooperation with the self-movable robot **80**.

The meaning of "before arriving at the next location" and the preparation are the same as described in the embodiment 1. For example, in a case where the robot controller **60** prepares for the job electronically, the before/after preparation control unit **503** transmits the required data in the job before or after the next job to the robot controller **60**. Further, for example, in a case where the robot controller **60** prepares for the job physically, the before/after preparation control unit **503** controls to replace the device such as a robot arm of the robot **70**. These preparations are the same as those of the self-movable robot **80**.

According to the modification example (4), before the self-movable robot **80** arrives at the next location, the robot controller **60** in that location is controlled to prepare for the job, and the next job can be thereby started quickly. This improves the production efficiency in the production system S. For example, if the robot controller **60** starts preparation for the job after the self-movable robot **80** arrives at the next location, the job cannot be started until all the preparations of the self-movable robot **80** are completed. By eliminating or shortening such waiting time, it is possible to improve the production efficiency.

(5) Further, for example, when the self-movable robot **80** arrives at the next location, there is a possibility that the self-movable robot **80** does not stop at the position or the

orientation as expected. In this case, if the self-movable robot **80** tries to perform the next job based on the downloaded data, a slight difference may occur and hinder the next job. As such, calibration for correcting the difference may be performed based on the state when the self-movable robot **80** arrives at the next location.

In the production system S of the present modification example, the setting unit **807** is implemented. The setting unit **807** is mainly implemented by the CPU **83** of the robot controller **82**. When the self-movable robot **80** arrives at the next location, the setting unit **807** sets the next job based on at least one of the current position and the orientation of the self-movable robot **80**. In the present modification example, both the position and the orientation are used, although only one of them may be used.

For example, a reference mark is arranged in the vicinity of the communication device **73** in the cell. The setting unit **807** detects the mark by the camera **88** and specifies the relative position to the mark and a deviation of the orientation to the mark (deviation from the position and the orientation that the self-movable robot **80** should originally be at and directed to). The setting data is generated so that there is no deviation in position and orientation, and thus the setting unit **807** corrects the setting data by the specified deviation. For example, the setting unit **807** performs reference alignment of the coordinate system for control based on the deviation. Further, for example, the setting unit **807** corrects the teaching data indicated by the setting data by the specified deviation to absorb the deviation.

According to the modified example (5), when the self-movable robot **80** arrives at the next location, the setting of the next job is performed based on at least one of the current position and the orientation of the self-movable robot **80**. This increases the job accuracy. For example, it is conceivable to move the self-movable robot **80** so as to eliminate the deviation of the position and the orientation of the self-movable robot **80**, but it takes time to move the self-movable robot **80**. As such, if the deviation is corrected by calibration, the job can be started earlier.

(6) Further, for example, the timing at which the self-movable robot **80** prepares for the next job may be the time when the movement to the next location is instructed by the instruction device **20**. As described in the embodiments 1 and 2, the instruction device **20** is communicably connected to the scheduling device **10** for scheduling a production plan, and provides instructions of each job based on the scheduling. The production plan is an overall plan in the production system S. For example, the production plan may indicate at least one of a product to be produced, the number of products, and a job period. The production plan is the content shown in the schedule data.

In this modification example as well, the transmitting unit **502** of the cell controller **50** transmits a predetermined job completion notification to the instruction device **20** when the current job of the robots **70** and **84** is completed. Upon receiving the job completion notification, the receiving unit **202** of the instruction device **20** instructs the self-movable robot **80** to move to the next location. These procedures are as described with reference to FIGS. **9** and **10**.

The preparation control unit **803** of the present modification example includes the fourth preparation control unit **803**F. The fourth preparation control unit **803**F controls the self-movable robot **80** to prepare for the next job when the instruction device **20** instructs the self-movable robot **80** to move to the next location. The fourth preparation control unit **803**F controls the self-movable robot **80** to prepare for the next job on condition that the self-movable robot **80** is instructed to move to the next location. The fourth preparation control unit **803**F controls the self-movable robot **80** not to prepare for the next job when the movement to the next location is not instructed, and allows the self-movable robot **80** to prepare for the next job when the movement to the next location is instructed. The methods of preparation of the self-movable robots **80** are as described in the embodiments 1 and 2.

According to the modification example (6), the scheduling device **10** schedules a production plan and the instruction device **20** gives a specific job instruction. As such, the roles of the respective devices are shared in the production system S, and this improves the efficiency of the production system S.

(7) For example, when the self-movable robot **80** arrives at the next location, the self-movable robot **80** may be made to transmit information about itself to the information collecting device **30**.

The production system S of this modification example includes the transmission control unit **808**. The transmission control unit **808** is mainly implemented by the CPU **83** of the robot controller **82**. When the self-movable robot **80** arrives at the next location, the transmission control unit **808** controls the self-movable robot **80** to transmit information relating to the self-movable robot **80** to the information collecting device **30**. The transmission control unit **808** controls the self-movable robot **80** to transmit information on the self-movable robot **80** to the information collecting device **30** on condition that the self-movable robot **80** arrives at the next location. As described in the embodiments 1 and 2, when the self-movable robot arrives at the next location, the communication is switched to wired communication, and thus the transmission control unit **808** controls the self-movable robot **80** to transmit the information about the self-movable robot **80** by using the wired communication.

The information relating to the self-movable robot **80** may be any information, for example, a name or an IP address of the self-movable robot **80**, a function of the self-movable robot **80**, trace data stored in the self-movable robot **80**, information detected by the sensors **87** and **94**, an image or video captured by the cameras **88** and **95**, or the current state of the self-movable robot **80**. The current state is, for example, a position, posture, remaining battery capacity of the self-movable robot **80**. The information transmitted to the information collecting device **30** is not limited to these examples, and any information may be transmitted.

According to the modified example (7), when the self-movable robot **80** arrives at the next location, the self-movable robot **80** is controlled to transmit information relating to the self-movable robot **80** to the information collecting device, and thus, it is possible to utilize the information, for example, to analyze the operation state of the self-movable robot **80** and increase the production efficiency.

(8) Further, for example, the above modification examples may be combined.

Further, for example, the self-movable robot **80** may have a function of switching communication without having the functions described in the embodiments 1 and 2. That is, the self-movable robot **80** may perform wireless communication during the movement and may switch to wired communication after arriving at the next cell without performing preparation for the next cell during the movement and synchronization after arriving at the next cell. For example, the self-movable robot **80** may transmit the trace data to the information collecting device **30** by the wireless communi-

cation while moving, and may switch to the wired communication when arriving at the next cell.

Further, for example, the case where the instruction device **20** issues the movement instruction has been described, although the movement instruction may be issued by another computer. For example, in a case where a movement plan of the day is recorded in advance in the AGV controller **90**, the self-movable robot **80** may determine the timing to move to the cell based on the movement plan.

For example, the case has been described in which each of the robot unit **81** and the AGV unit **89** of the self-movable robot **80** is provided with a communication function, but only one of them may be provided with a communication function. For example, only the robot unit **81** may have a communication function, and the AGV unit **89** may receive a movement instruction via the robot unit **81**. For example, only the AGV unit **89** may have a communication function, and the robot unit **81** may receive a movement instruction via the AGV unit **89**.

Further, for example, if sufficiently reliable wireless communication can be used, the self-movable robot **80** may not have a function of switching between the wireless communication and the wired communication. For example, the self-movable robot **80** may communicate with the cell controller **50** by wireless communication to perform the next job. In this case, the self-movable robot **80** may always perform wireless communication without having a function of wired communication. In contrast, if a communication cable does not interfere with the movement of the self-movable robot **80**, the self-movable robot **80** may prepare for the next cell by the wired communication. In this case, the self-movable robot **80** may always perform wired communication without having a function of wireless communication.

Further, for example, the case where the self-movable robot **80** can freely move to any cell has been described, although a cell to be handled by the self-movable robot **80** may be determined. For example, one self-movable robot **80** may be in charge of cells X and Y, and other self-movable robot **80** may be in charge of other cells. For example, the self-movable robot **80** may move within one cell. In this case, when completing the job of one cell, the self-movable robot **80** moves to a location in the cell where a post-process of the job is performed, and executes the post-process. At this time, preparation for the post-process may be made during the movement by the processing described in the embodiment 1, or synchronization may be performed after the movement by the processing described in the embodiment 2.

Further, for example, the processing of the production system S has been described by taking the example of the multi-type small-volume production, although the production system S may be applied to any other case. For example, the production system S may be applied to a one-type high-volume production. In this case, by executing the same processing as that described above, the self-movable robot **80** may move between the cells to perform the job. For example, if a failure occurs in a fixed robot **70** in a cell, the self-movable robot **80** may move to such a cell in order to execute the job instead of the robot **70**.

Further, for example, the case where the fixed robot **70** is disposed in the cell has been described, although the robot **70** disposed in the cell may move around in some degree. For example, the robot **70** may move on rails provided in the cell.

Further, for example, in the processing of S**1** in FIG. **9**, the scheduling device **10** transmits the schedule of the day to the instruction device **20**, although the scheduling device **10** may transmit only a part of the schedule of the day to the instruction device **20**. In this case, when confirming that the part of the schedule is completed, the instruction device **20** notifies the scheduling device **10** of such information. Upon receiving the notification, the scheduling device **10** refers to the schedule data and checks whether there is a next schedule. When it is determined that there is a next schedule, the scheduling device **10** transmits the rough job content of the next schedule to the instruction device **20**. Thereafter, the processing of S**2** and subsequent steps in FIG. **9** is executed, and the job of the next schedule is performed. When it is determined that there is no next schedule, which means all the job for the day is completed, and thus the scheduling device **10** may terminate the processing. For example, the instruction device **20** may transmit a job completion notification to the scheduling device **10** for each job, and may receive a schedule of the next job.

For example, the production system S may have a cell configured of only the self-movable robots **80**. In this case, a plurality of self-movable robots **80** gather and execute the job together. For example, each of the self-movable robots **80** performs the processing described in the embodiment 1 and prepares for the job to be performed in the cell prior to reaching the job space allocated to the cell. Further, for example, each of the self-movable robots **80** executes the processing described in the embodiment 2, and when arriving at the cell, synchronizes with other self-movable robots **80**. The cell controller **50** may be disposed in the job space of the cell, or may not be disposed in the job space of the cell. Similarly, the communication device **73** may be disposed in the job space, or may not be disposed in the job space. When the job in this cell is completed, each of the self-movable robots **80** proceeds to the next job, and thus the cell disappears. Furthermore, this cell may be configured of only one self-movable robot **80**.

For example, the case has been described in which the main functions are implemented by the self-movable robot **80**, although the functions described as being implemented by the self-movable robot **80** may be implemented by another device. For example, the movement control unit **801**, the communication control unit **802**, and the preparation control unit **803** may each be implemented by the instruction device **20** or another device. Further, for example, the job control unit **804** may be implemented by the cell controller **50** or another device. Further, for example, the synchronization control unit **805** may be implemented by the cell controllers **50** or other devices. The other functions may be similarly implemented by any device in the production system S. Further, for example, the data described as being stored in the production system S may be obtained from other system. Further, for example, the configuration of the production system S is not limited to the example of FIG. **1**. The production system S may include at least one self-movable robot **80**.

The embodiments described above have been shown as a specific example, and the present invention disclosed in this specification is not limited to the configurations of these specific examples and the data storage example itself. Those skilled in the art may make various modifications to the disclosed embodiment with regard to, for example, the shapes and numbers of physical components, data structures, and execution orders of processing. It is to be understood that the technical scope of the invention disclosed herein encompasses such modifications. In other words, it should be understood by those skilled in the art that various modifications, combinations, sub-combinations and altera-

tions may occur depending on design requirements and other factors insofar as they are within the scope of the appended claims or equivalents thereof.

What is claimed is:

1. A production system comprising:
an industrial device being self-movable; and
circuitry configured to:
control the industrial device to start to move towards a next location when the industrial device receives a movement instruction,
control the industrial device to download a job program and a parameter of a next job while the industrial device is moving towards the next location; and
control the industrial device to perform the next job based on the job program and the parameter when the industrial device arrives at the next location and downloading the job program and the parameter is completed.

2. The production system according to claim 1, wherein the circuitry is configured to:
determine whether a current job of the industrial device is completed; and
control the industrial device to prepare for the next job if it is determined that the current job is completed.

3. The production system according to claim 2, wherein the circuitry is configured to:
instruct the industrial device to move to the next location.

4. The production system according to claim 2, wherein the performance of the next job is different than performance of the current job.

5. The production system according to claim 4, wherein the circuitry is configured to execute the job program and use the parameter that includes a teaching data of the industrial device.

6. The production system according to claim 1, wherein the circuitry is configured to:
instruct the industrial device to move to the next location.

7. The production system according to claim 1, wherein the circuitry is configured to:
control the industrial device to download data to be used in the next job as the preparation for the next location; and
control the industrial device to perform the next job when the industrial device arrives at the next location and downloading of the data is completed.

8. The production system according to claim 1, wherein the circuitry is configured to:
control the industrial device to mount a device to be used in the next job; and
control the industrial device to perform the next job when the industrial device arrives at the next location and mounting of the device is completed.

9. The production system according to claim 1, wherein
another industrial device is disposed at the next location, and
the circuitry is configured to synchronize the industrial device with the another industrial device when the industrial device arrives at the next location.

10. The production system according to claim 9, wherein the circuitry is configured to control the industrial device to obtain, when the industrial device arrives at the next location, at least one of information on a state of the another industrial device, information on a state of a job object at the next location, or detected information of a peripheral device at the next location.

11. The production system according to claim 1, wherein
another industrial device is disposed at the next location, and
the circuitry is configured to control the another industrial device to prepare for a job to be performed before or after the next job before the industrial device arrives at the next location.

12. The production system according to claim 1, wherein
another industrial device and a communication device for a wired communication are disposed in the next location,
the circuitry is configured to control the industrial device to communicate using a wireless communication while the industrial device is moving towards the next location, and control the industrial device to communicate using the wired communication via the communication device when the industrial device arrives at the next location.

13. The production system according to claim 1, wherein the circuitry is configured to execute a setting of the next job based on at least one of a current position or a current orientation of the industrial device when the industrial device arrives at the next location.

14. The production system according to claim 1, wherein
the industrial device includes an automatic guided vehicle and a robot performing the next job.

15. The production system according to claim 1, comprising:
an instruction device configured to be communicably connected to a scheduling device scheduling a production plan, and provide an instruction of each job based on the schedule; and
a transmitter configured to transmit a predetermined job completion notice to the instruction device when a current job of the industrial device is completed,
wherein
the instruction device is configured to receive the predetermined job completion notice;
the instruction device is configured to instruct the industrial device to move to the next location when the job completion notice is received, and
the circuitry is configured to control the industrial device to prepare for the next job when a movement to the next location is instructed by the instruction device.

16. The production system according to claim 1, wherein the job program indicates a procedure from a start to an end of the next job in time series.

17. The production system according to claim 1, wherein the circuitry is configured to control the industrial device to download the job program and the parameter of the next job after the industrial device starts to move towards the next location.

18. The production system according to claim 17, further comprising an instruction device configured to transmit the movement instruction to the industrial device, wherein the circuitry is configured to:
receive the movement instruction from the instruction device, generate a movement path to the next location based on the movement instruction, and control the industrial device to move towards the next location based on the movement path.

19. A non-transitory information storage medium having stored thereon a program that causes a computer to:
control the industrial device to start to move towards a next location when the industrial device receives a movement instruction,

control an industrial device being self-movable to download a job program and a parameter of a next job while the industrial device is moving towards the next location; and

control the industrial device to perform the next job based on the job program and the parameter when the industrial device arrives at the next location and downloading the job program and the parameter is completed.

* * * * *